

AGE DIFFERENCES IN ATTENTION:  
A PSYCHOPHYSIOLOGICAL APPROACH

By

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Dedicated, with love and gratitude, to

Marian E. Saffer

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## TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	iii
ABSTRACT.....	vii
CHAPTER	
1 INTRODUCTION.....	1
The Startle Reflex.....	2
Reflex Inhibition.....	5
Reflex Facilitation.....	9
Reflex Latency Modification.....	15
Cognitive Contributions.....	18
The Aging of Attentional Processes.....	24
2 GENERAL METHODOLOGY.....	29
Subjects.....	29
Apparatus.....	29
Procedure.....	32
Data Analysis.....	33
3 EXPERIMENT 1.....	35
Method.....	38
Results.....	40
Conclusions.....	46
4 EXPERIMENT 2.....	51
Method.....	52
Results.....	54
Conclusions.....	58
5 EXPERIMENT 3.....	60
Method.....	65
Results.....	67
Conclusions.....	71
6 EXPERIMENT 4.....	75
Method.....	77
Results.....	78
Conclusions.....	80

7	DISCUSSION.....	82
	APPENDIX. EXPERIMENT 1: HEART RATE ANALYSES.....	101
	REFERENCES.....	107
	BIOGRAPHICAL SKETCH.....	115

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It is possible to inhibit elicited reflexes by preceding the eliciting stimulus (ES) by a prestimulus (PS). This project tested the hypothesis that the PS engages the attentive faculties so that an ES following thereafter does not have complete access to these processes. The ES is therefore rendered functionally less intense, resulting in a smaller reflex.

It was predicted that in young subjects, manipulations designed to facilitate either automatic or effortful attention toward the PS would increase the amount of reflex inhibition. It was further hypothesized that only attempts to manipulate automatic attention would successfully increase the amount of inhibition in elderly subjects.

These issues were investigated in a series of four experiments. In each experiment, eyeblink and heart rate (HR) responses were measured subsequent to a periorbital airpuff. In the first three experiments, a 70 decibel tone PS preceded the ES in a variety of temporal formats. In the fourth experiment, gaps in a continuous tone served as prestimuli.

Experiment 1 was designed to manipulate automatic attention. Twenty-seven young and 27 elderly subjects received 54 trials. On nine trials, the ES was presented alone. On 48 trials, the ES was preceded by a tone of 20 or 200 milliseconds (msecs), at interstimulus intervals of 60, 120, 240, or 420 msecs. Results revealed greater eyeblink inhibition with the longer PS in both age groups. The effect of PS duration did not interact with age. The HR response in both age groups was biphasic, with a deceleration followed by an acceleration. In the young subjects, the PS augmented the size of the deceleration, and to a lesser extent, the acceleration, more so for the longer PS. The elderly HR was not affected by the PS.

Experiment 2 attempted to manipulate effortful attention. On 25 trials, the ES was preceded by a PS of one of two frequencies, either 500 Hertz or 1000 Hertz (the "common" PS). On five trials, the other PS was presented (the "rare" PS). The ES was presented alone on 15 trials. One half of the 40 young and 40 elderly subjects were



instructed to count the number of rare prestimuli. This manipulation had no effect upon eyeblink inhibition or HR modification in either age group.

Experiment 3 was also designed to manipulate effortful attention. In three conditions, 24 young and 24 elderly subjects received six ES-alone trials and six in which the ES was preceded by a 1000 Hertz, 70 decibel PS, at an interstimulus interval of 120 msec. In Conditions 2 and 3, a reaction time task was included in the procedure. In Condition 2, a reaction time response was required at random intervals. In Condition 3, the response was required five seconds after ES. The reaction time task increased the amount of eyeblink inhibition and the size of the HR deceleration in young but not in elderly subjects.

Experiment 4 investigated the effects of a gap in a continuous tone of 10, 20, 40, 80, and 120 msec preceding the ES by 120 msec, in 16 young and 16 elderly subjects. The amount of eyeblink inhibition increased with increasing gap duration. Neither age group evidenced effects of the PS on the HR response.

The results of these experiments support four conclusions: 1) the amount of eyeblink inhibition is affected by manipulations of attention, 2) automatic attention is more completely preserved into old age than is effortful attention, 3) prestimulation augments the decelerative component of a biphasic HR response in young

subjects, and 4) heart rate responses are obtainable in the elderly; however, they are less plastic than those of younger subjects.

## CHAPTER 1 INTRODUCTION

Basic reflexes have intrigued psychologists for many years. Perhaps due to the reliability of reflexive behavior or possibly to the status of physiological reflexes as predictors of neurophysiological functioning and integrity, reflexes have played a central role in many historically prominent psychological theories.

Various reflexes such as kneejerks elicited by taps to the patellar tendon and eyeblinks elicited by airpuffs or sudden sounds can be modified by changes in the sensory environment. Depending upon stimulus parameters, the magnitude and latency of an elicited reflex can be increased or decreased by prior stimulation.

It will be my purpose in this dissertation to investigate the extent to which attention contributes to the reflex modification process. In addition, the phenomenon will be investigated in young and old adults with the hope of shedding light upon possible mechanisms underlying reported decreases in attentional capacity in old age.

### The Startle Reflex

The startle reflex was studied in detail by Landis and Hunt (1939). Using extremely rapid photographic equipment, these investigators thoroughly described the topography of the human startle reflex. As they described it, the startle consists of a generalized and largely symmetrical contraction of the flexor musculature. This pattern includes an eyeblink, forward head movement, abduction of the upper arms, flexion of the elbows, fingers, and knees, pronation of the lower arms, forward movement of the trunk, hunching of the shoulders, and abdominal contraction.

The eyeblink is the first component of the reflex to appear, having an onset latency of about 40 milliseconds (msecs). The other muscular components appear about 60 msecs after onset of the eliciting stimulus (ES). According to Landis and Hunt (1939), reflexive behavior is distinguishable from voluntary responses to the ES by the greater latency of voluntary responses (about 150 msecs). The temporal order of the reflex was described as beginning with an eyeblink and then passing down over the rest of the body.

Landis and Hunt (1939) also described autonomic nervous system components of startle. In particular, they reported a decrease in skin resistance and a heart rate (HR) acceleration occurring at a latency of 500 msecs to 1000 msecs. In addition, they reported an initial respiratory

inspiration followed by an elevated rate of respiration and a rise in systolic blood pressure. In a review of the HR literature, Graham (1979) concluded that Landis and Hunt (1939) were correct in their report of an acceleration as a component of startle.

In ascribing a brief HR acceleration to the startle, Graham (1979) depended heavily upon Fleshler's work (Fleshler, 1965) in order to specify stimulus configurations likely to produce a startle response. Fleshler (1965) concluded that the critical stimulus parameters for startle elicitation in rats were stimulus intensity and suddenness or rise time. He found that as ES rise time increased (i.e. the ES became "less sudden"), the threshold intensity for startle elicitation also increased. He concluded that rise time per se was not as critical as the requirement that the ES reach a certain intensity within the first 10 to 15 msec. This work was a follow-up of studies by Hoffman and Fleshler (1963) and Hoffman, Fleshler, and Alplanalp (1964) demonstrating increasing response magnitude with increasing ES intensity.

K. M. Berg (1973) investigated effective ES parameters in humans and found that the reflex was affected by both ES rise time and duration. Berg's findings indicated that, contrary to Fleshler's (1965) conclusion, the latency and amplitude of startle eyeblinks were affected by variations in ES duration and rise time well beyond this 10 to 15 msec

range. Berg suggested that the startle reflex is controlled by 2 neural systems. A system of short time-constant neurons which summate spatially but not temporally was hypothesized to produce a primary component of startle, including the eyeblink in humans and muscular flexion in rats. The longer latency HR response was attributed to a secondary component of startle. This component was hypothesized by Berg to be controlled by a system of long time-constant neurons which are able to summate temporally but not spatially. These neural systems have been described by Gersuni (1965,1971). In support of Berg's (1973) dual-component hypothesis, Pinckney and Ison (1979) found very little correlation between lead stimulus effects upon the flexion and cardiac startle responses in rats. At this point, it seems reasonable to conclude that startle elicitation is primarily responsive to ES rise time, although the 10 to 15 msec interval is probably not as critical as hypothesized by Fleshler (1965).

Finally, there is disagreement upon the exact form of the HR response to startle-eliciting stimuli. In agreement with Landis and Hunt (1939) and Graham (1979), Fleshler (1965) and Chalmers and Hoffman (1973) found a HR acceleration. In contrast, Berg (1973) and Pinckney and Ison (1979) found a biphasic response with an initial deceleration followed by an acceleration.

### Reflex Inhibition

Since the late nineteenth century it has been known that various aspects of elicited reflexes can be modified by changes in the sensory environment. Bowditch and Warren (1890) investigated the effects of stimuli in various modalities upon the magnitude of kneejerks elicited by taps to the patellar tendon. The basic stimulus configuration consisted of a prestimulus (PS) followed by an interstimulus interval (ISI) followed by the ES. The effect of the PS upon reflex magnitude was either inhibitory or facilitative, depending upon the ISI.

After this early demonstration of reflex modification with sensory stimuli, the effect was not investigated for the next 35 years. In 1926, Dodge and Louttit published a report of investigations into reflex magnitude as a function of the ISI between successive presentations of the ES. Measuring the effects of ISIs ranging from approximately 180 to 500 msec, they found that the response to the second stimulus was uniformly smaller than that to the first. They attributed this effect to refractoriness in the startle mechanisms. In addition to any refractoriness, it is probable that the first stimulus was serving as an inhibitory PS. Shortly after the Dodge and Louttit (1926) study, several investigations of reflex modification were reported from Yale University. Hilgard (1933) reported that the ISI between the PS and the ES was critical for the

effect of the PS. Cohen, Hilgard, and Wendt (1933) used the inhibitory effects of visual PS to demonstrate that the peripheral blindness reported by a patient was not of organic etiology. Though the patient could not report seeing stimuli in his peripheral fields, these stimuli did effectively inhibit his response to sudden noise. Subsequent to these and several other studies in the 1930's, the paradigm was again ignored until 1963. In 1963, Hoffman and Fleshler noticed that the magnitude of elicited startle was increased in the presence of background noise. However, when the noise pulsed on and off with a 500 msec duty cycle, the reflex was greatly inhibited. This paper initiated an area of research which has continued to the present.

Probably the most crucial parameter determining the effects of a PS upon an elicited startle is the ISI between the PS and the ES. Hoffman and Searle (1965) found that a 10 msec noise burst presented shortly before the ES (ISI = 20 to 160 msecs) served to inhibit the elicited reflex. This demonstration replicated the findings of Hilgard (1933). However, Hilgard (1933) found that the reflex was inhibited at ISIs equal to 100 to 425 msecs and facilitated at ISIs of 20 to 50 msecs. Hoffman and Searle (1965) found only inhibition at ISIs of 20 to 160 msecs. The fact that inhibition can be seen at very short ISIs is important for ruling out the possibility that the inhibition is due to protective reflexes of the middle ear, since these



protective reflexes occur much more slowly than the inhibition process. Also, inhibition can be seen with stimuli much too weak to elicit such protective reflexes (e.g. Marsh, Hoffman and Stitt, 1978). This possibility is also ruled out by the fact that reflex inhibition can be seen with prestimuli of a different modality from the ES (e.g. Bowditch and Warren, 1990; Marsh, Hoffman, and Stitt, 1976; Pinckney, 1976; Schwartz, Hoffman, Stitt, and Marsh, 1976; Reiter and Ison, 1977; and Sanes, Ison, and Adelson, 1978). It is also unlikely that the effect is due to auditory masking of the ES by the PS, since inhibition is relatively insensitive to the frequency characteristics of the stimuli (Marsh, Hoffman, Stitt, and Schwartz, 1975) whereas masking is frequency-dependent.

In several parametric studies of the effects of ISI, it has been found that the PS has little effect upon reflex amplitude for ISIs less than about 20 msecs. Similarly, inhibition is usually not seen at ISIs greater than 500 to 1000 msecs. In rats, maximum inhibition is seen at ISIs of about 50 msecs (Ison and Hammond, 1971; Schwartz, Hoffman, Stitt, and Marsh, 1976; Fechter and Ison, 1972), although some have reported maximum inhibition at longer ISIs (e.g. Ash, Parisi, and Ison, 1978; Stitt, Hoffman, and Marsh, 1973). Beyond 100 msecs, the inhibitory effect diminishes to zero by about 1000 msecs (Ison and Hammond, 1971). In humans, the pattern is similar except that maximum

inhibition is seen at somewhat longer ISIs, usually 100 to 150 msec (Graham and Murray, 1977; Sanes, Ison, and Adelson, 1978) although maximum inhibition at shorter ISIs has been seen (Krauter, Leonard, and Ison, 1973).

In addition to ISI, PS intensity determines its inhibitory effect. Hoffman and Wible (1970) used auditory prestimuli ranging in intensity from 35 to 95 dB to inhibit acoustic startle in rats. They found that as PS intensity increased, reflex amplitude decreased. This effect was replicated by Krauter, Leonard, and Ison (1973). Similarly, Marsh, Hoffman, and Stitt (1978) found that as the auditory PS increased in intensity, airpuff-elicited eyeblinks decreased in amplitude in humans. Also using a puff-elicited eyeblink, Reiter and Ison (1977) found that increases in the intensity of a visual PS had the same effect as reported above for auditory prestimuli. Finally, Pinckney (1976) used several intensities of shock as the PS and found that whole-body acoustic startle in rats was a decreasing function of increasing shock intensity.

In summary, reflex inhibition is a robust phenomenon which has been demonstrated for a number of reflexes (e.g. eyeblink and kneejerk in humans, whole-body startle in rats, pigeons, and guinea pigs) and for a number of eliciting stimuli (acoustic, visual, tactile) as well as prestimuli (acoustic, visual, tactile). The effect is evident primarily at ISIs between 20 and 500 msec and increases with PS

intensity. It should be emphasized that an effective prestimulus need not consist of a discrete tone or light or any other addition of energy to the sensory environment. Stimulus offset (Stitt, Hoffman, and Marsh, 1973) as well as a change in the frequency characteristics of continuous noise (Stitt, Hoffman, Marsh, and Boskoff, 1974; Marsh, Hoffman, Stitt, and Schwartz, 1975) has been used as inhibitory stimuli. Indeed, it seems that virtually any change in the sensory environment can serve as an inhibitory PS, given the appropriate temporal configuration.

### Reflex Facilitation

Quite early in the literature, it was discovered that the same PS can inhibit or facilitate the magnitude of elicited reflexes depending upon the ISI. As mentioned above, Hilgard (1933) found reflex inhibition when the PS preceded the ES by 25 to 50 msecs. Bowditch and Warren (1890) also noted opposite effects of a PS depending upon the ISI. More recently, it has generally been shown that short intervals (e.g. 20 to 500 msecs) produce inhibition, whereas ISIs greater than 1000 msecs are usually necessary in order to see amplitude facilitation.

Hoffman and Fleshler (1963) found that with rats a continuous background noise level of 85 dB facilitated the amplitude of elicited reflexes whereas turning the noise on and off every 500 msecs inhibited the reflex. In this case,

the inhibitory effects of the pulsed background were probably due to the changes in stimulation occurring within 500 msec of the ES. The effects of continuous noise are often ascribed (e.g. Graham, 1975) to activation of an arousal system (see Malmö (1959) for a discussion of arousal). Hoffman and Searle (1965) found that as background noise intensity increased from 50 to 90 dB, reflex facilitation also increased. Hoffman and Wible (1970) compared the effects of a 75 dB noise stimulus initiated at intervals ranging from 100 to 6400 msec before ES onset. In addition, the PS was either present until ES onset or turned off after 20 msec. With the continuous PS, the reflex was facilitated for stimulus onset asynchronies (SOAs) greater than or equal to 400 msec. However, with the discrete PS, all intervals less than 3200 msec produced inhibition and facilitation was not evident at any of the intervals. The authors concluded that facilitation and inhibition were independent processes and that facilitation was a function of stimulation present at the time of ES initiation.

Ison, McAdam, and Hammond (1973) produced a situation in which the PS was initiated at various intervals before the ES and terminated only after ES presentation. The SOA varied from 0 to 2000 msec. In agreement with Hilgard (1933), facilitation was seen at short SOAs (5 and 10 msec), while inhibition was seen at SOAs of 20 to 170 msec. The apparent contradiction of these results with

those finding facilitation only at long ISIs can possibly be resolved by reference to two recent papers. Hoffman and Stitt (1980) and Hoffman, Cohen, and Stitt (In press) found that stimuli presented simultaneously with an effective ES will augment the elicited reflex even when the stimuli are of insufficient intensity to elicit the reflex themselves. The short time-constant system, hypothesized by Berg (1973) to control the initial skeletal components of startle, is able to summate stimuli presented within 15 msec of one another. Thus stimuli with SOAs less than 15 msec may both contribute to startle elicitation. Therefore, short SOA facilitation is probably a function of the total amount of stimulation present at or near ES initiation. The facilitation seen in experiments on rats differs in some respects from that found in the next group of studies to be reviewed, which used human subjects.

Graham, Putnam, and Leavitt (1975) investigated the effects of either continuous or 14 msec prestimuli presented at SOAs ranging from 200 to 2000 msec before ES initiation. As expected, both the continuous and the discrete prestimuli inhibited the reflex at the 200 msec SOA. At 800 msec, neither PS affected the reflex. However at 1400 and 2000 msec, both the discrete and the continuous prestimuli facilitated the reflex. These results replicated the data from rats in all respects except one. In rats, no facilitation had been seen with discrete prestimuli. Graham

(1975) accounted for the disparity between rats and humans by referring to two distinct facilitative processes. She proposed that facilitation due to background stimulation and to continuous prestimuli may be due to general arousal. She further speculated that facilitation produced by discrete prestimuli was due to physiological rebound triggered by ES presentation. Since Graham, Putnam, and Leavitt (1975) found a HR deceleration during the interval between PS and ES, it was hypothesized that the PS produced an orienting response (HR deceleration is a component of the orienting response) because the PS signalled the beginning of an uncertain interval which ends at ES presentation. Initiation of the ES eliminates this uncertainty, terminates orienting, and produces a physiological rebound. Presumably, this orienting-related uncertainty does not occur in rats and thus, neither does facilitation due to discrete prestimuli.

Bloch and Toukatly (1976) directly tested the hypothesis of reflex facilitation due to stimulus uncertainty. They presented a discrete PS at a long ISI (2000 msecs) before the ES. The PS was one of three different visual stimuli. One indicated that the ES would follow with 100% certainty, one indicated a 50% probability of ES presentation, and the third indicated 100% certainty of no ES. In support of Graham's (1975) hypothesis, they found facilitation in the 50% but not in the 100% certainty condition.

Bohlin and Graham (1977) speculated that if facilitation is due to a termination of orienting, any manipulation which caused orienting to persist through the ES should prevent facilitation. One half of their subjects were required to discriminate the duration of a soft tone presented within the 2000 msec PS to ES interval. The other half were required to estimate the duration of the ES. It was hypothesized that the latter subjects would show no facilitation since orienting would hopefully be maintained through the entire ES. The results were negative. Both groups of subjects evidenced equal amounts of facilitation. However, since both groups showed a HR acceleration following the ES, there was no evidence that the second group continued to produce an orienting reaction through the ES.

In a second experiment from the same paper, Bohlin and Graham (1977) chose a subsample of subjects who did show HR deceleration through the ES and evaluated the effects of the PS. Even in this group, the PS produced facilitation. These results therefore argue against the notion that facilitation is due to termination of orienting. Since HR deceleration is thought to enhance sensory input (e.g. Sokolov, 1960, 1963; Lacey, 1967; Lacey, Kagan, Lacey, and Moss, 1963), Bohlin and Graham (1977) speculated that the PS initiates orienting which enhances ES input and thus facilitates startle.

Silverstein and Graham (1978) tested this possibility by requiring subjects to judge the duration of an electrotactile stimulus presented simultaneously with the ES. It was hypothesized that by directing attention away from the acoustic ES facilitation would be prevented. In fact, when this procedure was employed, the PS produced no facilitation. Considered in conjunction with the Bohlin and Graham (1977) paper, these findings suggested to the authors that discrete PS facilitation is due to the direction of attention to the ES by the PS.

In summary, there seem to be two distinct processes which can produce reflex amplitude facilitation. The facilitation evident at short ISIs as well as that produced by background noise seems to be a function of the total stimulus energy present at ES initiation. This may be a result of stimulus-produced arousal (Graham, 1975), or due to the total effect of several sources of stimulation, each having independent access to neural sites responsible for reflex initiation (Hoffman, Cohen, and Stitt, In press). In contrast, reflex facilitation produced by discrete prestimuli at long ISIs seems to be a process unique to humans, since it is not reliably observed in other species, and may involve relatively sophisticated cognitive processes. If the PS serves to direct the respondent's attention toward the ES (possibly also producing a HR deceleration during the PS-ES interval), the reflex will be facilitated.



### Reflex Latency Modification

The discussion has thus far focused upon modification of reflex amplitude. Various stimulus parameters also have reliable effects upon reflex latency. Hoffman, Fleshler, and Alplanalp (1964) discovered that reflex latency in rats decreased with increasing ES intensity, an effect replicated by Berg (1973) in humans. Fleshler (1965) found no effect of ES rise time or duration upon latency, a finding incompatible with those of Berg (1973) who found decreasing reflex latency with increasing ES duration. In terms of ES parameters, it can be said generally that in humans the same manipulations which increase reflex amplitude serve to decrease reflex latency.

The presentation of a FS before the ES has effects upon reflex latency in addition to those upon reflex amplitude. Hilgard (1933) found that the same ISIs which resulted in amplitude inhibition (75 to 450 msec) also decreased the latency of elicited eyeblinks in humans. More recently, Hoffman and Searle (1968) reported that SOAs of 5 to 15 msec reduced latency in rats even though there were no effects upon amplitude at the 5 msec SOA. This effect was replicated by Ison, McAdam, and Hammond (1973) who found latency reduction at SOAs of 5 and 10 msec but (contrary to Hilgard, 1933) latency increase for SOAs at or beyond 40 msec. Stimulus onset asynchronies greater than 170 msec

had no effect upon reflex latency. The authors also found that increasing the intensity of background noise produced increases in reflex latency. Hoffman and Wible (1970) also found increased latency with increasing PS intensity, but only at an ISI of 150 msec. At an ISI of 5 msec, increases in PS intensity produced decreases in response latency. Schwartz, Hoffman, Stitt, and Marsh (1976) found latency reduction at SOAs of 2, 4, and 8 msec (but not at 1 and 64 msec) as well as larger amounts of latency reduction with increasing PS intensity. Pinckney (1976) found latency increases at 40 and 250 msec ISIs, but no effect at 10 or 1000 msec. Stitt, Hoffman, and Marsh (1976) similarly found that an SOA of 4 msec reduced latency whereas an SOA of 64 msec increased it.

In humans, PS effects upon latency have not been as extensively investigated as in the studies reviewed above using rats, rabbits, and pigeons. Reiter and Ison (1977) found increased latency with increasing PS intensity, a finding at variance with those of Schwartz, Hoffman, Stitt, and Marsh (1976). However, the 100 msec ISI employed by Reiter and Ison corresponds closely to the 150 msec ISI used by Hoffman and Wible (1970) who also found increasing latency with increasing PS intensity. The 5 msec ISI condition of Hoffman and Wible (1970) produced decreasing latency for increasing PS intensity, a finding replicated by Schwartz, Hoffman, Stitt, and Marsh (1976) with a 4 msec

SOA. Graham and Murray (1977) found reduced reflex latency for ISIs of 30 and 60 msec, increased latency at 120 msec, and no difference at 240 msec.

The studies of response latency reviewed thus far have used ISIs within the range which normally produces amplitude inhibition. Bloch and Toukatly (1976) presented the PS at an ISI of 2000 msec (thereby producing amplitude facilitation) and found a decrease in latency, a finding replicated by Bohlin and Graham (1977) and Silverstein and Graham (1978). The latency reduction was relatively unaffected by the various manipulations of attention in these last three studies.

In summary, the latency of elicited reflexes is affected by variations in PS and ES parameters as is reflex amplitude. Increases in ES intensity produce decreases in reflex latency. In rats, ES duration and rise time have so far shown no effect upon latency. However, in humans the latency of elicited reflexes has been shown to decrease with increasing ES duration. The addition of a PS produces independent effects upon latency. At ISIs between 5 and 60 msec, reflex latency is reduced. Interstimulus intervals between 60 and 200 msec produce increases in reflex latency. Increasing the ISI to 2000 msec again reduces latency. The effects of PS intensity are complex. At short ISIs (e.g. 5 msec), increases in PS intensity produced decreases in reflex latency. At longer ISIs (e.g. 150

msecs), increases in PS intensity produce increases in reflex latency. Finally, as with amplitude inhibition, latency can be reduced by changes in the bandwidth of a noise PS (Marsh, Hoffman, Stitt, and Schwartz, 1975) and by stimulus offset (Stitt, Hoffman, and Marsh, 1973).

In concluding the review of the literature concerning the effects of various stimulus parameters upon reflex modification, it should be mentioned that the amplitude inhibition and latency reduction effects seem to be independent of variables affecting reflex elicitation. For example, Stitt, Hoffman, and Marsh (1976) found that ISI effects did not differ for ES intensities ranging from 90 to 120 dB. Hoffman, Marsh, and Stitt (1980) found that not only is amount of inhibition independent of ES intensity, but so is the amount of latency reduction.

### Cognitive Contributions

Until very recently, reflex modification was investigated largely from a physiological or stimulus-parametric standpoint. If any attempt was made to relate the phenomena to psychological processes, it was usually by calling upon rather global terms such as arousal. However, it has been known for some time that various cognitive processes can affect elicited reflexes. Lombard (1887) investigated the effects of various psychological "states" upon the magnitude of elicited kneejerks. Among other

interesting relationships, Lombard (1887) found that he could reduce the apparent intensity of the ES (Lombard served as his own subject) as well as the magnitude of the response by ". . . directing the thoughts to some indifferent subject, for instance, by quietly concentrating the attention on the warmth of the skin of the hand" (p. 47).

Explicit attempts to cast the effects of reflex facilitation in a psychological framework have been made by Graham and her colleagues. For example, Bohlin and Graham (1977), Bloch and Toukatly (1976), and Silverstein and Graham (1978) demonstrated that the phenomenon of reflex facilitation depends not only upon the parameters of stimulation, but also upon the meaning ascribed to the stimuli. Bohlin and Graham (1977) suggested that reflex facilitation may occur because the PS signals the approach of the ES and thus directs attention toward it. Bloch and Toukatly (1976) found that if the PS signalled the approach of the ES only uncertainly, the facilitative effect was enhanced. Finally, Silverstein and Graham (1978) reported that a manipulation designed to focus attention away from the ES prevented the facilitative effects of an appropriately placed PS, which instead inhibited the reflex.

The attempt to account for reflex inhibition in cognitive terms is more recent and tentative. Graham (1975) speculated that reflex inhibition may be a method of

protecting preattentive processing. Drawing upon Neisser's (1967) concept of preattentive processing, Graham characterized startle as an interrupt system, designed to halt ongoing cognitive activity and free the organism to deal with incoming stimulation. The effect of the inhibitory PS is to minimize the distracting effects of a full-blown startle. Hoffman and Ison (1980), in a review of the reflex modification literature, proposed their own model to account for the effects of facilitative and inhibitory prestimuli. This largely neurophysiological model postulates independent excitatory and inhibitory systems acting upon a startle system.

A brief review of the characteristics of a potent inhibitory PS indicates a relatively simple principle: given the appropriate temporal relationships, the "bigger" or more salient the PS, the greater is its inhibitory potency. For example, inhibition increases as PS intensity increases. In addition, when using a frequency shift in a continuous tone or band of noise as a PS, the larger the shift the greater is the amount of inhibition. The same manipulations which tend to increase the inhibitory effect of a PS are the same as those which tend to decrease psychophysical thresholds (Weber, 1834, cited in Gescheider, 1976).

If it is assumed that the organism has a facility for detecting discrete stimulation, and if it is further assumed that various stimulus parameters determine to what extent

this facility is engaged, it is possible to propose a model of reflex modification based upon this facility. Neisser (1967) describes such a process and refers to it as "preattentive processing." When coining the term, Neisser (1967, p. 89) described preattentive processing as a preliminary analytical operation which serves to separate objects from ground ". . . which later mechanisms are to flesh out and interpret." The process serves to separate an object from others ". . . as a potential framework for the subsequent and more detailed analyses of attention." In short, preattentive processes serve to locate and identify figures from ground, or signal from noise, and to render these unities as material for subsequent cognitive analyses. If it is further assumed that this process takes a finite amount of time, it is possible to conceive of reflex inhibition as due, in part, to the "capture" or engagement of the attentive and preattentive processes. If the ES arrives very shortly after the PS, it is rendered functionally less intense by the fact that the PS has engaged the preattentive processes. This model can also account for the effects of ISI upon inhibition. At very short ISIs, the PS has not yet fully engaged the processes by the time the ES arrives so, there is little inhibition. At long ISIs, there is ample time for the PS to be detected and for the processes to be disengaged and then re-engaged by the ES, again producing little inhibition.

Although the proposed model is couched in terms usually associated with an information-processing approach, it is quite compatible with other approaches to cognitive psychology. For example, Gibson (1966) speaks of a process of resonance wherein the person extracts information from the energy available at the sensory receptors. Gibson further posits that some structures in the environment are more attractive than others. "Certain loci in the array contain more information than others. The peripheral retina registers such a locus, the brain resonates vaguely, and the eye is turned. Subjectively we say that something 'catches our attention'" (1966, p. 260).

In support of the proposed model, it has been found that equal intensity eliciting stimuli are judged less intense if they are preceded by a PS (Cohen, Hoffman, and Stitt, In press). The effect was independent of the magnitude of the response to the ES. DelPezzo and Hoffman (1980) found that if their subjects were instructed to attend to the PS there was greater inhibition than if the subjects were instructed to ignore it. They proposed a model very similar to the attentional model that I have outlined. The authors referred to a characterization of attention proposed by Posner, Snyder, and Davidson (1980): "Attention can be likened to a spotlight that enhances the efficiency of detection of events within its beam" (p. 172). In support of this conceptualization, Posner, Snyder, and Davidson



(1980) found that reaction times to a stimulus were decreased if the stimulus appeared in an expected position and increased if it appeared in an unexpected position.

Viewed in this way, results of older studies are consistent. For example, Lombard's (1987) finding that he could reduce the apparent intensity of taps to the patellar tendon as well as the magnitude of the elicited kneejerks by concentrating on unrelated matters supports the proposed conceptualization. In addition, Peak (1931) found that elicited eyeblink reflexes were facilitated if the subject was required to react rapidly to the ES by moving a finger or making a voluntary lid movement. In terms of the attentional model, Lombard (1987) was directing attention away from, and Peak (1931) was directing attention toward the ES. More recently, Boelhouwer (1979) found that the R2 component of the eyeblink (that component which accounts for the majority of actual lid movement) was smaller during the period between the warning stimulus and the imperative stimulus in a reaction time task. If it is assumed that attention in this case was being directed toward the imminent imperative stimulus and away from the ES, these results can be construed as support for the attentional model proposed.

This model can be extended to account for facilitation of reflex amplitude seen with discrete prestimuli at long ISIs. It is possible that the PS is presented at a lead

interval long enough in this case to allow voluntary aspects of attention to be directed toward the upcoming ES. In agreement with Bohlin and Graham (1977), the HR deceleration often seen between PS and ES in these long ISI situations may be an index of this sort of attentional preparation.

### The Aging of Attentional Processes

The literature on the adult development of attention reveals marked differences in attentional and perceptual processes in old age (see Hoyer and Plude, 1980 for a review). The changes in attentional behavior can be summarized by two general maxims: 1) performance on tasks designed to measure attentional and perceptual processes (as is true for virtually any behavior) tend to slow with age; 2) as task demands increase, age differences in performance also increase.

The evidence for the slowing of perceptual behavior with age comes from a variety of sources. For example, older people need longer exposures in order to identify briefly presented forms (Salthouse, 1976), have lower flicker fusion thresholds (Weale, 1965) and click fusion thresholds (Weiss, 1963), and require longer ISIs in order to avoid visual masking effects (Walsh, Williams, and Hertzog, 1979).

At least two attempts to account for this behavioral slowing have been made by prominent gero-psychologists. Botwinick (1978, p. 157) has postulated that the central

nervous system of the older person needs a greater time to "clear" a stimulus out, in effect producing a greater "stimulus persistence." This idea was originally formulated to account for the phenomena mentioned above as well as other age-related behavioral changes (e.g. less precise judgements of sequentially lifted weights and greater susceptibility to visual illusions). There have been subsequent studies supporting increased stimulus persistence in the aged, including investigations of the ability to integrate sequentially presented word halves (Kline and Orme-Rogers, 1978) as well as other, mostly tachistoscopic, studies. The stimulus persistence model is very similar to "integration" models of visual masking (see Turvey, 1973, for a review), and it is therefore not surprising that it relies heavily upon studies of visual perception for its support. The general idea is that humans do not have perfect temporal resolution abilities so that if one stimulus follows another in close temporal proximity, the person is left with a "double exposure" out of which he attempts to make sense. Botwinick proposes that this persistence increases with age.

Birren (1965, 1974) has also proposed a model to account for behavioral slowing in the elderly. He likens the behavior of the elderly to a calculator or electric motor operating on less than optimal voltage. According to Birren, an insufficient operating voltage causes a

calculator to perform more slowly. However, since a calculator loses no information, it will perform its functions correctly. In contrast, human cognitive processes are subject to information loss due to decaying stimulus or memory traces. So unlike a calculator, the slower old person may have more difficulty on some tasks, because during the greater time required to carry out certain functions, more information is lost than by quicker young persons. The implications of this model are subtle but noteworthy. Birren proposes that speed of processing is important for the accuracy of such diverse behaviors as visual perception, learning, motor skills, and intelligence. Indeed, Birren (1974) suggests that ". . . one may regard the changes with age in central processing time as the major independent variable in explaining much of the behavioral changes with age" (p. 813).

The second maxim can be construed to predict age by task complexity interactions for most tasks. That is, as the attentional demands of the task increase, so do the age differences in performance. Perhaps a fruitful avenue of approach to this issue is one adopted by Hoyer and Plude (1980). These investigators drew upon various models of attention (e.g. Hasher and Zacks, 1979) which distinguish between automatic attention (e.g. tasks which tap highly practiced skills) and effortful attention (e.g. tasks in which new strategies or conscious efforts to maintain

vigilance are required). Generally, it has been found that tasks which require effortful attention show much greater age differences than those which largely require automatic attention (e.g. Plude and Hoyer, 1980).

The experiments undertaken here will involve various manipulations designed to increase the salience (and thus, hopefully the "attention-getting" value) of the PS in a reflex inhibition situation. This will be attempted by strategies designed to direct either automatic or effortful attention to the PS. On the basis of the literature reviewed above, it was hypothesized that increasing either automatic or effortful attention to the PS would enhance its inhibitory effect upon the elicited reflex, but that smaller age differences would occur with manipulations of automatic than of effortful attention.

Stated briefly, the purposes of the research to follow are threefold; 1) to test an attentional model of reflex inhibition, 2) to investigate age differences in reflex inhibition produced by manipulations of attention, and 3) to juxtapose the models of age-related slowing proposed by Birren and Botwinick. The investigation will be informative for at least two reasons. First, these models were formulated based largely upon data from reaction time and visual perception research. Subsequent tests of Botwinick's model have typically employed similar methods. It would be informative to test the models not only with a radically

different methodology, but with an involuntary response. Kline and Scheiber (1981) have indicated the need for such a departure from traditional investigative methodology in this regard. The use of an elicited reflex will hopefully minimize problems of interpretation due to age differences in motivation or experimental anxiety. Secondly, a direct test of these two models has not yet been attempted. Such a test would be heuristically valuable in the sense of more precisely channelling future progging for the processes underlying the observed behavioral slowing in old age.

## CHAPTER 2 GENERAL METHODOLOGY

### Subjects

The young subjects in these studies ranged in age from 17 to 30 and were recruited from the Department of Psychology subject pool. Subjects participated in experiments in order to fulfill requirements of the Introductory Psychology class. Old subjects were recruited through the Alachua County Older Americans Council of Gainesville, Florida. Subjects received no remuneration for their participation. Subjects were not screened on the bases of health, sensory acuity, or socioeconomic status with the exception of several elderly subjects whose data were eliminated from the analyses due to obvious severe hearing loss or use of a cardiac pacemaker.

### Apparatus

Stimulus timing and presentation as well as eyeblink response measurement were controlled on-line by a PDP 8/E laboratory computer. Airpuff stimuli were produced by electronically opening a solenoid valve fitted on a pressure-regulated scuba tank. The air was directed through

plastic tubing to an adjustable fitting mounted on the headset used to deliver tone stimuli. This fitting allowed presentation of the airpuff stimuli virtually anywhere on the right side of the face. For all experiments to be reported here, the opening of the airhose was positioned about one centimeter posterior to the outer canthus of the right eye at a distance of one centimeter from the skin surface. The intensity of the airpuff was measured by connecting a manometer from a blood pressure sphygmomanometer (Abco #HR18104-390102) to the end of the airhose. The relationship between the steady-state pressure and the momentary pressure of the airpuff stimuli was established by using a Narco Bio-Systems Physiograph (Model DMP 4B), Strain Gage Coupler (Type 7172) and pressure transducer (#700-1010). Puff intensities were controlled by an Airco, Inc. regulator (#806-9106).

Tone stimuli were produced by a Hewlett-Packard wide range oscillator (Model 200CD) or a Krohn-Hite function generator (Model 5300). Sine wave tones were gated through Iconix electronic switches (#6837). Tone intensities were controlled with a Hewlett-Packard attenuator (#350D) and tones were presented through TDH-49 earphones fitted with MX-41/AR cushions. Rise/decay times for all tone stimuli were set at 5 msecs. Tone frequencies were visually checked with a Textronix dual-channel storage oscilloscope (Model R564E). Tone intensities were checked with a Hewlett-



Packard volt meter (Model 400E), which was calibrated with a Bruel and Kjaer sound level meter (Type 2203), fitted with a six cubic centimeter coupler, and calibrated with a Type 4132 microphone.

Responses were recorded on a Beckman polygraph (Model S411E) using Type 9806A A-C couplers. Time constants and high frequency filtering were as follows; for electrocardiogram (ECG), high frequency filters were set at 22 Hz and time constant at .004 Hz, for electrooculogram (EOG), high frequency filters were set at 22 Hz and time constant at .1 Hz.

Electrooculogram was sampled on-line at the rate of 1/msec and stored on floppy disk for subsequent off-line analysis. Electrocardiogram, EOG, and a pulse coincident with airpuff delivery were also stored on channels 1, 2, and 4, respectively of a Hewlett-Packard 3960 Instrumentation FM tape recorder. The tape was replayed for heart rate analysis.

All testing was done in an IAC 10983 sound-attenuating chamber which was located in a room separate from all equipment. With the door to the room closed and the door to the chamber open, ambient sound level was approximately 35 dB(A). Electrocardiogram and EOG were recorded using Beckman Ag/AgCl 11 mm cup electrodes (#650437), adhesive collars, and Synapse electrode cream (Med-Tek Corporation). For recording EOG, small areas above the left eyebrow and above

the left cheekbone were lightly abraded with Redux Paste and wiped clean before application of the electrodes. For ECG, electrodes were attached to the volar surface of the left and right forearms or below the midline of the right clavicle and to the left ankle. A ground electrode was attached to the left forearm (or left ankle). No ungrounded devices operating on line voltage were within reach of the grounded subjects. Subjects were continuously monitored over closed-circuit television and two-way communication was available via intercom.

#### Procedure

Subjects were brought into the laboratory and first read and signed an informed consent agreement. Upon completion of the informed consent form, subjects were seated in the IAC chamber and any experimental instructions were given in an informal manner as the electrodes were attached and the headset placed in position. Considerable effort was undertaken to make the situation as non-threatening as possible, as there is evidence that physiological responses are subject to variation due to the measurement setting (Harbin and Cunningham, 1978). After all electrodes were in place, subjects were asked to relax while the recording equipment was turned on and gain settings adjusted. This took about five minutes. Then, the instructions were repeated, questions answered, and the door to the room was closed. The door to the IAC chamber was

always left open to maintain good air circulation. At the conclusion of the session, the purposes of the experiment and the polygraph records were discussed with the subjects.

#### Data Analysis

Voltage changes associated with the elicited eyeblinks were sampled once per msec for 250 msec following initiation of the airpuff stimuli. Offline analysis later measured onset latency, onset voltage level, peak voltage level, and blink amplitude (equal to peak voltage minus voltage at onset). A graphic depiction of the response was displayed on a Tektronix Type 602 cathode ray tube and measured from this display with a computer-guided cursor and readout of voltage levels at each msec.

The HR data were analyzed by replaying the recorded ECG. Channel 1 of the tape was played through an Iconix Schmitt Trigger (#6804) with the reference voltage level set to give a pulse coincident with each R-wave. The computer was programmed to measure the R-R intervals to the nearest msec for two seconds before and 12 seconds after the airpuff initiation. These intervals were later transformed into average HR/second in accordance with Graham's (1978) recommendations. The data analyses to be reported were carried out using the last second before and the first five seconds following the airpuff.

Unless otherwise noted, data were statistically analyzed using the P2V routine of the BMDP 1979 statistics

package. In order to correct for violations of sphericity (Hunyh and Feldt, 1970), the Hunyh and Feldt (1976) estimator of the Box (1954) corrective adjustment for degrees of freedom was calculated for all significant within-subject contrasts. The observed  $F$  statistic was tested a critical  $F$  with reduced degrees of freedom (see Hunyh and Feldt, 1976 for a discussion of this procedure). Contrasts which were significant with full, but not with reduced degrees of freedom, will be noted in the text. Since the  $F$  statistic is not seriously biased by departures from normality, conformity with this assumption was not evaluated.

### CHAPTER 3 EXPERIMENT 1

The discussion in Chapter 1 emphasized that those manipulations which serve to lower sensory thresholds (or increase stimulus salience) are also those which tend to increase the inhibitory potency of a particular PS (e.g. increased PS intensity). In terms of the dual-process model of attention, these manipulations are likely affecting automatic attention to a greater extent than effortful attention. An obvious PS manipulation which has not yet been discussed in terms of reflex inhibition is that of varying PS duration. Increasing stimulus duration produces decreases in its intensity threshold (within limits) and should therefore produce increasing amounts of inhibition if the attentional model is accurate.

Graham, Putnam, and Leavitt (1975) investigated the effects of discrete (duration = 14 msec) and continuous prestimuli presented at various SOAs. The continuous PS was terminated at ES presentation. At the shortest SOA employed (200 msec), equal amounts of inhibition were produced by the two PS durations. Similarly, Graham and Murray (1977)

found no difference between 20 msec and continuous PS durations at SOAs ranging from 30 to 240 msec. Thus there was apparently no effect of PS duration upon the amount of inhibition, contrary to the prediction of the attentional model.

One possible explanation for the negative findings in this regard lies in the use of a continuous PS as opposed to one whose duration varies, but is always terminated well before ES initiation. Since the magnitude of an elicited reflex is not only a function of the ES but of other stimulation present at ES initiation (Cohen, Hoffman, and Stitt, In press), the continuous PS may have both inhibited the reflex (due to PS onset within the inhibitory range) and facilitated the reflex by increasing the total amount of stimulation present at ES initiation. Thus any additional inhibition engendered by the longer PS may have been nullified by its facilitative effects.

Dykman and Ison (1979) presented prestimuli of three durations (2, 20, and 200 msec) and two intensities (55 and 85 dB) at 150 msec ISI. They used both rats and humans as subjects. For the rats, the ES was a 120 dB tone and the measured response was whole body startle. For the humans, the ES was a small shock delivered to the skin over the supraorbital branch of the trigeminal nerve and the measured response was eyeblink.

Both rats and humans demonstrated more inhibition with the more intense PS, as expected. In addition, the rats showed increasing amounts of inhibition with increasing PS duration at both PS intensities. This was true for the humans for the 55 dB PS. With the 85 dB PS, the humans evidenced greater inhibition for the 20 msec PS than for the 2 msec PS, but the 200 msec PS produced slightly less inhibition than the 20 msec PS.

These results apparently support the attentional model's prediction of increasing inhibition with increasing PS duration. Unfortunately, interpretation of these data is difficult due to the authors' method of controlling ISI. Dykman and Ison (1979) set the interval between PS and ES at 150 msec, measured from the midpoint of the PS to the onset of the ES. This resulted in a situation in which PS duration covaried with onset-to-onset as well as offset-to-onset times. Since both PS onset and offset can serve as inhibitory stimuli, it is not possible in the Dykman and Ison study to separate effects due to PS duration from those due to onset-to-onset and offset-to-onset times.

In this experiment, the effects of two PS durations were observed at four ISIs in two age groups. In accordance with the attentional model, it was expected that the longer PS would produce more inhibition. Since it was hypothesized that varying PS duration would affect automatic attention, age differences in the amount of inhibition were expected to

be minimal. However, since most perceptual processes seem to be slower in the elderly, the usual U-shaped ISI function was expected to be shifted toward greater ISIs in the elderly group.

Prestimulus durations and ISIs were chosen so as to provide a means of assessing the effects of PS duration independent of SOA and ISI. The duration of the PS was either 20 or 200 msecs, and ISIs were equal to 60, 120, 240, or 420 msecs (measured from PS offset to ES onset). Thus offset-to-onset times did not covary with PS duration. In addition, four of the conditions served as a control for onset-to-onset times. The 20 msec PS, 240 msec ISI and the 200 msec PS, 60 msec ISI both resulted in SOAs of 260 msecs. Similarly, the 20 msec PS, 420 msec ISI and the 200 msec PS, 240 msec ISI resulted in an SOA of 440 msec.

### Method

#### Subjects

There were 54 participants in this study, 27 young and 27 old. The young group was comprised of 13 females and 14 males ranging in age from 17 to 27 years (mean = 20.0). The old group was comprised of 13 females and 14 males ranging in age from 57 to 77 years (mean = 68.4). Twelve additional young subjects were eliminated from the analyses, 11 for producing fewer than three scoreable blink responses per condition and one due to the qualitatively abnormal



appearance of the eyeblink responses. Nine elderly subjects were eliminated, five for insufficient data, two for procedural error, one for obvious severe hearing impairment, and one for past traumatic injury to the left eye.

### Procedure

The experiment included nine treatment conditions, eight of which consisted of a PS followed after a variable ISI by the ES. The ninth condition was a presentation of the ES alone with no preceding ES. The PS was a 1000 Hz sine wave presented at 70 dB(A) for either 20 or 200 msec. Rise/fall time for the PS was set at 5 msec. The ISI was set at one of four values: 60, 120, 240, 420 msec (offset-to-onset). The ISI was terminated by a 50 msec airpuff set at an intensity of 80 mm Hg. ( $80 \text{ mm Hg} = 10,665 \text{ N/(m}^2\text{)} = 1.55 \text{ psi}$ .) The two PS durations were combined factorially with the four ISIs to produce eight conditions. These eight plus the ES-alone control condition were randomly combined into a  $9 \times 9$  latin square. Subjects proceeded through six rows of the latin square for a total of 54 trials, six in each condition. For the purpose of counterbalancing order of treatment presentation, subjects started at different rows of the latin square. Preliminary analyses indicated that neither the effect of row nor any of its interactions were significant. Randomly occurring intertrial intervals equaled 15, 20, 25, 30, or 35 secs, with a mean of 25 secs over the experiment.

## Results

### Eyeblink

Eyeblink magnitude for each subject was averaged within each of the nine conditions. The mean amplitude of the control response for each subject was then subtracted from the other eight condition means. These difference scores were then corrected for the gain setting and comprised the data for the analyses to be reported. The use of absolute difference scores rather than percent difference has been supported by data reviewed by Hoffman and Ison (1980).

The data (depicted in Figure 1) were submitted to a 2 AGE X 2 PS durations (DUR) X 4 ISI analysis of variance. The results of this analysis revealed, first of all, that the 200 msec PS produced more inhibition than the 20 msec PS ( $F(1,52)=39.41$ ,  $p<.0001$ ). Secondly, the effects of ISI and DUR X ISI were also significant ( $F(3,156)=3.54$ ,  $p=.0162$ , and  $F(3,156)=4.31$ ,  $p=.0059$ ). A Newman-Keuls followup test indicated that the 200 msec PS produced more inhibition than the 20 msec PS at all ISIs except 420 msec. There was neither an effect of AGE on the amount of inhibition, nor did AGE interact with DUR. However, the AGE X DUR X ISI was significant ( $F(3,156)=2.93$ ,  $p=.0354$ ).

Due to the significance of the AGE X DUR X ISI interaction, the data were analyzed separately for the young and old subjects. For both groups the data were analyzed with a 2 DUR X 4 ISI analysis of variance. In the young

group, all contrasts were significant, including DUR ( $F(1,26)=17.19$ ,  $p=.0003$ ), ISI ( $F(3,78)=4.84$ ,  $p=.0039$ ), and DUR X ISI ( $F(3,78)=6.53$ ,  $p=.0005$ ). The pattern was quite different for the old subjects. The effect of DUR was still highly significant ( $F(1,26)=22.45$ ,  $p=.0001$ ). But neither the ISI nor the DUR X ISI contrasts were significant.

The results of the analysis thus far implied several conclusions. First, increasing the duration of the PS produced increases in the amount of inhibition in both age groups. Second, the effect of ISI was much stronger in the young than in the old. Third, the effect of ISI interacted with PS duration strongly in the young group ( $p=.0005$ ) and marginally in the old ( $p=.089$ ).

As a result of these interactions, orthogonal trends over ISI were evaluated within each group at each PS duration. In the young subjects, the amount of inhibition for the 20 msec PS increased with increasing ISI. This was confirmed by a significant linear trend ( $F(1,26)=11.95$ ,  $p=.0019$ ) and nonsignificant quadratic and cubic trends. For the 200 msec PS the ISI effect was U-shaped, as expected from the literature. The quadratic trend was significant ( $F(1,26)=8.71$ ,  $p=.0066$ ), while the linear and cubic components were not.

In the old group, there was no significant ISI effect for the 20 msec PS. The ISI main effect, as well as all component trends, produced  $F$  values less than 1.00. For the

200 msec PS however, the ISI effect approached significance ( $F(3,78)=2.56$ ,  $p=.0613$ ) and the expected U-shaped function was evident. This was supported by a significant quadratic trend ( $F(1,26)=8.73$ ,  $p=.0066$ ) and nonsignificant linear and cubic trends.

In order to address the possibility that the significant PS duration effects were due to different onset-to-onset times (SOAs), a final analysis of variance was undertaken with four of the eight conditions. The 20 msec PS, 240 msec ISI and the 200 msec PS, 60 msec ISI each resulted in SOAs of 260 msecs. Similarly, the 20 msec PS, 420 msec ISI and the 200 msec PS, 240 msec ISI produced SOAs of 440 msecs. These four conditions were submitted to a 2 AGE X 2 SOA X 2 DUR analysis of variance. The results indicated a strong effect of DUR ( $F(1,52)=12.58$ ,  $p=.0008$ ). In addition, the greater SOA produced more inhibition than the shorter ( $F(1,52)=8.49$ ,  $p=.0053$ ). The AGE effect and all interactions were not significant.

### Heart Rate

Heart rate responses were measured for one second before and five seconds following the airpuff. The responses were averaged second by second yielding nine responses per subject, one for each condition. Heart rate responses from trials which did not produce scoreable eyeblinks were not included in these averages. The responses, averaged within condition and age group, are depicted in Figure 2.

The initial step in the analysis was undertaken in order to determine if there was a reliable HR response and whether this response was affected in any way by the stimulus conditions or age. Data were analyzed with a 2 AGE X 9 conditions (COND) X 6 seconds (SEC) analysis of variance. Results first indicated no effect for AGE or COND, implying that there were no differences in overall HR level between age groups or among the stimulus conditions. This will facilitate unambiguous interpretation of results since the law of initial values (Wilder, 1950) is not likely to complicate further analyses. (A subsequent analysis provided additional support for this conclusion by finding no effect of stimulus condition on the prestimulus point.) The COND X SEC X AGE contrast was significant when tested with full ( $F(40,1920)=1.65$ ,  $p=.0068$ ) but not with reduced degrees of freedom ( $.10 > p > .05$ ). This can be taken as weak evidence that the stimulus conditions affect the shape of the response differently for young and old subjects. Significant COND X SEC ( $F(40,1920)=2.52$ ,  $p<.0001$ ) and AGE X SEC ( $F(5,240)=5.49$ ,  $p=.0001$ ) effects implied that the shape of the response was affected by the conditions and was different for the two age groups. The significant COND X AGE effect ( $F(8,384)=2.33$ ,  $p=.019$ ) indicated that the overall HR level was affected differently by the conditions in the two age groups. Finally, the highly significant SEC effect ( $F(5,240)=24.72$ ,  $p<.0001$ ) confirmed the robust HR response to the airpuff.

Perusal of Figure 2 reveals that the main component of the HR response seems to be an initial HR deceleration peaking at 1 to 2 secs and a return to prestimulus level. The addition of a PS produces a secondary acceleration peaking at 4 to 5 secs. The size of the deceleration as well as the acceleration appears to be a function of stimulus condition. Due to the significant AGE interactions, analyses of variance for 9 CCND X 6 SEC were undertaken within the two age groups.

The complexity of these analyses preclude presentation here. A detailed description is provided in the Appendix. The results of the analyses indicated that stimulus condition had no effect upon the elicited HR response of the elderly. The young subjects however, revealed a robust effect of condition. The next step in the analysis dealt with specifically with the effects of PS duration and ISI. The elderly evidenced no effect of PS duration, ISI, or their interaction upon the shape of the HR and strongest at the middle ISIs. The PS tended to accentuate the decelerative component of the response, and to a lesser extent, the accelerative component. The effect was greater with the 200 msec PS than with the 20 msec PS.

The next step in the analysis dealt specifically with the accelerative and decelerative components of the response. Separate DUR X ISI analyses of variance were conducted for the first poststimulus second (the point of

maximum deceleration) and the fourth poststimulus second (the point of maximum acceleration) within the two age groups. The elderly revealed no effects upon either the deceleration or the acceleration. The young subjects also evidenced no effect upon the acceleration. However, the decelerative component showed significant effects due to DUR ( $F(1,49)=12.27$ ,  $p=.0010$ ) and ISI ( $F(3,147)=3.03$ ,  $p=.0314$ ).

The final analysis conducted served as a control for PS onset to ES onset time effects. As with the eyeblink responses, the 20 msec PS, 240 msec ISI and the 200 msec PS, 60 msec ISI produced SOAs of 260 msec. Similarly, the 20 msec PS, 420 msec ISI and the 200 msec PS, 240 msec ISI produced SOAs of 440 msec. These four conditions were submitted to a 2 DUR X 2 SOA X 6 SEC analysis of variance in the young and old groups separately. For the old subjects, neither DUR or SOA or their interaction interacted with SEC, indicating again no effect of DUR upon the elicited response. For the young subjects, DUR interacted with cubic SEC ( $F(1,25)=6.06$ ,  $p=.0211$ ), indicating that even controlling for onset-to-onset times, the 200 msec PS affects the elicited HR response more than the 20 msec PS. In addition, the DUR X SOA X SEC effect ( $F(5,125)=2.33$ ,  $p=.0467$ ) was marginally significant.

### Conclusions

The results from analyses performed upon the eyeblink data demonstrated a robust effect of DUR upon the amount of inhibition. This finding replicated those of Dykman and Ison (1979) and did so while controlling for onset-to-onset and offset-to-onset times. The fact that greater duration prestimuli produce more inhibition is also in line with predictions of the attentional model of reflex inhibition proposed here.

It is also apparent that it is possible to inhibit the eyeblink in elderly subjects and that the effect is every bit as robust as in younger subjects. One of the hypotheses of this study was not supported, however. It was predicted that, since most responses slow with age, the ISI function of the elderly should be shifted toward greater values compared to the young. This was obviously not the case. If anything, the point of maximum inhibition occurred earlier in the old, as is evident in Figure 1.

Perusal of Figure 1 also reveals that these data are at variance with the literature in some respects. For example, with the 200 msec PS the young subjects exhibited maximum inhibition at an ISI of 240 msec. This is much later than the 100 to 150 msec nadir usually seen (e.g. Graham and Murray, 1977). The pattern is even more anomalous with the 20 msec PS. At this PS duration, the young subjects demonstrated increasing inhibition with increasing ISI



whereas the old subjects failed to demonstrate any effect of ISI whatsoever. This finding could be due to the use of an airpuff ES. Most studies investigating the effect of ISI have used acoustic eliciting stimuli. It is possible that the airpuff elicited some combination of the startle and corneal reflexes and that these combined reflexes respond somewhat differently to changes in ISI, especially at short PS durations.

The HR response seen in this experiment was primarily decelerative. This finding is at variance with the conclusion of Graham (1979) that the HR component of startle is a small, brief acceleration. In support of Graham (1979), Chalmers and Hoffman (1973) found a monophasic acceleration in rats on control trials which was reduced in magnitude by the addition of a PS at an SOA of 100 msecs. Pinckney and Ison (1979) however, found a pattern somewhat similar to that reported here. Their rats evidenced a triphasic (acceleration-deceleration-acceleration) response. They presented a PS at an SOA of 60 msec which reduced the magnitude of the initial acceleration and the deceleration.

The response in humans seems to be primarily decelerative. Berg (1973) reported a deceleration and indicated that there was no evidence of an acceleration even on early trials. Clarkson (1979) found a deceleration (peaking at 1 to 2 secs poststimulus) which was modified by the PS into an acceleration (peaking at 4 to 5 secs). The

present results are similar to Clarkson's in finding a deceleration on control trials. The addition of the PS added a later accelerative component peaking at about the same latency.

It seems inappropriate to speak of the effects of the PS on the elicited HR response as inhibitory. Unlike the eyeblink, the decelerative and (to a lesser extent) the accelerative components of the HR response were magnified by the PS. This result contradicts the finding by Chalmers and Hoffman (1973) of PS-inhibited HR acceleration. However, the effects reported here were larger for the 200 msec than for the 20 msec PS and the magnitude of the effects generally exhibited a U-shaped ISI function. In this regard, the results are clearly consistent with the eyeblink data.

The age comparisons were not consistent across the two response systems. The eyeblink data demonstrated very few age differences. The DUR and ISI effects as well as response magnitudes were quite similar. This supported the prediction of few age differences proposed under the assumption that manipulating PS duration would affect automatic attention. The ISI function, however, did not conform to prediction. Based upon time-dependent studies of perceptual behavior (e.g. visual masking), it was predicted that the elderly would show a similar ISI function but that it would be shifted toward later times. If anything, the elderly function was shifted toward earlier times. This discrepancy

may be due to the use here of an involuntary response as opposed to the usual practice of employing voluntary responses.

The heart rate data evidenced marked age differences. Essentially, the elderly HR response was unaffected by any of the experimental manipulations. It was not the case however, that the elderly heart was not responsive. The response was robust, unlike previous studies showing little or no HR responsivity in the elderly (e.g. Morris and Thompson, 1969; Shmavonian, Miller, and Cohen, 1970; Botwinick and Thompson, 1971). This fact tends to discount the possibility that decreased arterial elasticity (Hallock and Benson, 1937), decreased baroreceptor sensitivity (Nelson and Gellhorn, 1958), decreased cardiac muscle responsivity (Frolkis, Shevtchuk, Verkhatsky, Stupina, Karpova and Lakiza, 1979), or other physiological changes known to reduce HR responsivity in old age can account for the lack of effects demonstrated here.

In summary, the eyeblink data generally conformed to the predictions of the attentional model. There was greater inhibition for longer prestimuli and this effect was consistent across age groups. The HR data did not conform to a pattern of reflex inhibition, though the DUR and ISI manipulations were effective in the young subjects. The elderly subjects demonstrated an absence of HR modifiability though the ES produced a robust HR response. The

inconsistency of results between the eyeblink and the HR response systems seems to support Berg's (1973) conclusion that these represent two distinct neural systems, a conclusion also supported by the data of Pinckney and Ison (1979) who found very small correlations between cardiac and whole-body startle in rats.

#### CHAPTER 4 EXPERIMENT 2

It has been demonstrated that manipulations designed to "automatically" increase PS salience tend to increase its inhibitory effect upon elicited reflexes. There is evidence that instructions designed to purposefully direct attention to the PS have similar effects. DelPezzo and Hoffman (1980) presented subjects with a semicircle of lights, any one of which served as a PS on any given trial. Instructions to attend to a particular light increased that light's inhibitory effect relative to the others, while instructions to ignore a particular light produced the opposite effect. This effect was evident even though the subjects did not move their eyes.

The following experiment was undertaken in order to test this effect with a different manipulation and to investigate age differences in the effectiveness of the experimental conditions. In order to cause subjects to "effortfully" direct attention to the PS, an experimental strategy was adopted from evoked cortical potential research. Two tones of different frequencies served as

prestimuli. One (labelled the "common" PS) occurred more often than the other (labelled the "rare" PS). Subjects were assigned to two groups, one of which was instructed to count the rare tone and the other of which was not. If it is assumed that instructions to count the rare PS would direct attention toward the PS, it could be predicted that the counting groups would evidence more inhibition.

Based upon the adult development literature on attention (see Hoyer and Plude, 1980, for a review), it could be predicted that this manipulation would be more effective in the young than in the old subjects, since the elderly seem to be less able to allocate attention effortfully.

### Method

#### Subjects

There were 20 young males and 20 young females in this experiment, ranging in age from 17 to 26 years (mean=19.4 years). The old group consisted of 20 males and 20 females ranging in age from 57 to 86 years (mean=69.2 years). Four additional young subjects were eliminated from the analyses, three for failing to produce at least three scoreable eyeblink responses per condition and one due to equipment failure. Six old subjects were eliminated, two for too few responses, three for use of a hearing aid, and one for past traumatic injury to the left eye.

### Procedure

Stimuli in this experiment again consisted of a tone PS followed after an ISI of 120 msec by a 50 msec airpuff ES. The PS had an intensity of 70 dB(A), a duration of 50 msec, and rise/fall times of 5 msec. The ES was delivered at an intensity of 80 mm Hg. The PS was set at one of two frequencies, 500 Hz or 1000 Hz.

Subjects received three stimulus configurations. The first consisted of an airpuff-alone control condition. The other two conditions consisted of the PS followed by the airpuff. One of the tone prestimuli was designated the rare PS and occurred on 11% of the trials. The common PS occurred on 66% of the trials. The remaining 33% of the trials were control trials. These trial types were randomly arranged into nine rows of nine conditions with the restriction that each row contained one rare prestimulus, six common prestimuli, and three control trials. Subjects started at different rows of the 9 X 9 stimulus table and proceeded through five rows for a total of 45 trials. This resulted in the presentation of five rare tones, 25 common tones, and 15 control trials.

After being connected to the recording equipment, all subjects were told that they would hear high and low tones and were given examples of each. One half of the subjects in each of the four age by sex groups were then instructed to count the number of rare tones presented, while the other

half were not so instructed. The pitch of the rare tone (either high or low) was counterbalanced within each of the eight age by sex by experimental groups. Following the session, all subjects were asked the number of rare tones presented.

### Results

In order to have an index of the success of the instructions in directing attention toward the PS, the number of rare tones counted was analyzed with a 2 AGE X 2 experimental groups (GRP) analysis of variance. The significant GRP effect ( $F(1,76)=13.03$ ,  $p=.0005$ ) indicated (not surprisingly) that the group instructed to count the rare tones was more accurate in estimating the number actually presented (5.9 vs. 11.5). The significant AGE effect ( $F(1,76)=4.12$ ,  $p=.0458$ ) indicated that the old counted the tones more accurately than the young subjects (7.1 vs. 10.3). The interaction was not significant.

### Eyeblink

The mean responses from the trials with a PS were subtracted from the mean response on the control trials and corrected for the gain. These two gain-corrected differences comprised the data for each subject. Overall means are depicted in Figure 3.

The data were first analyzed with a 2 AGE X 2 stimulus configuration (STIM) X 2 GRP analysis of variance. None of



the effects reached significance, though the AGE effect was close ( $F(1,76)=3.92$ ,  $p=.0514$ ). For exploratory purposes, the data were also analyzed separately in the two age groups.

For the old subjects, there was a marginally significant effect for STIM ( $F(1,36)=4.34$ ,  $p=.0443$ ). No other effects were significant. For the young subjects, none of the effects reached significance. Therefore the attempt to affect inhibition by having subjects count one of the two prestimuli was unsuccessful. Overall, there was significant inhibition  $F(1,76)=128.97$ ,  $p<.0001$ , but the stimulus conditions did not affect the amount of response reduction. The within-subject factor of PS frequency was effective in the old subjects, but the effect was small and opposite the direction predicted (i.e. the common PS produced greater inhibition).

#### Heart rate

As in the first experiment, the HR data were analyzed over the last second before and the first five seconds following ES presentation. These data are depicted in Figure 4, and were first analyzed with a 2 AGE X 3 STIM X 2 GRP X 6 SEC analysis of variance. This analysis revealed a significant SEC effect ( $F(5,380)=13.00$ ,  $p<.0001$ ) implying that there was a reliable response to the ES. The significant AGE X SEC effect  $F(5,380)=3.07$ ,  $p=.0099$  indicated that the shape of the response was different in the two age groups. There were no other significant effects.

Due to the AGE X SEC interaction, the data were analyzed separately within the young and old groups and analyzed for trends with STIM X GRP X SEC analyses of variance.

In the old subjects, there was a significant SEC effect ( $F(5,190)=10.43$ ,  $p<.0001$ ). This effect was composed of a large cubic component ( $F(1,38)=39.69$ ,  $p<.0001$ ), substantial quadratic component ( $F(1,38)=15.61$ ,  $p=.0003$ ), and a marginally significant quintic component ( $F(1,38)=4.22$ ,  $p=.0470$ ). These findings corroborate those from Experiment 1 in finding a biphasic response composed of an initial deceleration followed by an acceleration.

The young subjects revealed an almost identical pattern. Again, the SEC contrast was highly significant ( $F(5,190)=7.47$ ,  $p<.0001$ ). This contrast was composed of a strong cubic component ( $F(1,38)=37.28$ ,  $p<.0001$ ), and a smaller linear trend ( $F(1,38)=6.93$ ,  $p=.0122$ ). None of the other contrasts were significant in either group. These results are consistent with those from the eyeblink data in finding no effect for experimental instructions and little or no effect of PS frequency.

Due to the very strong cubic trends evident in both age groups, analysis of the points of maximum deceleration and acceleration may be informative. If these analyses also revealed no significant effects, it would be very difficult to argue against the conclusion that the experimental manipulations had no effect. Therefore, the first and fourth

poststimulus seconds were submitted to a 2 AGE X 3 STIM X 2 GRP analysis of variance. Results of the analysis for the deceleration revealed a significant STIM effect ( $F(2,152)=3.48$ ,  $p=.0334$ ), as well as a STIM X AGE interaction ( $F(2,152)=4.26$ ,  $p=.0159$ ), implying that the stimulus configuration did affect the decelerative component of the response, but differently for the young and old subjects. In addition, the AGE X GRP interaction was significant ( $F(1,76)=4.09$ ,  $p=.0466$ ), implying that the decelerative component was affected differently by the experimental instructions in the two age groups.

Due to the significant AGE interactions, the decelerative component was analyzed separately with STIM X GRP analyses of variance in the young and old groups. For the old subjects, none of the effects reached significance. For the young subjects, the STIM effect was significant ( $F(2,76)=5.20$ ,  $p=.0076$ ), indicating that the stimulus configuration altered the decelerative component of the elicited HR response. This effect was the result of a larger deceleration with the rare FS.

The results of the analysis of the fourth poststimulus second (the point of maximum acceleration) revealed only a significant AGE effect ( $F(1,76)=5.76$ ,  $p=.0189$ ), indicating that this component of the elicited HR response was more prominent in the young than in the old subjects.

It can be seen in Figure 4 that the control trends for the young and old appear topographically dissimilar. Whereas the response of the elderly subjects appears to be a deceleration and return to baseline, the young response was apparently a late acceleration and return. This difference was analyzed with a 2 AGE X 2 GRP X 6 SEC analysis of variance on the control responses. The analysis revealed a significant SEC effect ( $F(5,380)=5.81, p<.0001$ ), which was composed primarily of a cubic component ( $F(1,76)=27.03, p<.0001$ ), and a much smaller linear component ( $F(1,76)=4.35, p=.0404$ ). None of the other effects reached significance. This confirmed the biphasic nature of the responses and indicated that it was not affected by age or experimental instructions.

### Conclusions

In terms of the attentional model of reflex inhibition, the results of this experiment imply one of two conclusions. It is possible that reflex inhibition is a function only of automatic attention and that direction of effortful attention has no effect upon the process. This seems unlikely in light of the findings of DelPezzo and Hoffman (1980). These researchers found that the instruction to ignore or attend to a particular PS significantly affected the amount of inhibition it engendered. In addition, it has been found that acoustical thresholds for eyeblink

elicitation are elevated when subjects are allowed to read (K.M. Berg, personal communication, 1981).

The second, and more likely conclusion, is that the procedure utilized in this experiment was not powerful enough in terms of directing attention. The difference between a 500 Hz tone and a 1000 Hz tone presented for 50 msec at 70 dB is quite salient and possibly required very little attentional effort. Under the assumption that this was the case, Experiment 3 was designed with the purpose of more forcefully engaging effortful attentional processes.

## CHAPTER 5

### EXPERIMENT 3

This experiment was designed for the purpose of manipulating effortful attention by incorporating a reaction time (RT) task into the reflex modification procedure. Since it has been demonstrated that there is a reliable HR deceleration during the foreperiod of a warned reaction time task (e.g. Lacey, 1967) and since HR deceleration is thought to be a component of orienting (Graham and Clifton, 1966), it is conceivable that the procedure could be utilized for the purpose of directing attention toward or away from selected stimuli.

Ison and Ashkenazie (1980) instructed their subjects to respond to an airpuff ES by pressing a button as rapidly as possible. The ES was preceded by either a "warning stimulus" at an ISI of 120 msec, a "discriminative stimulus" at an ISI of 100 msec, or both of these stimuli. The warning stimulus alone produced a small facilitative effect upon the eyeblink and in addition, seemed to slightly increase the inhibitory effect of the discriminative stimulus when they were presented together. If it is assumed that the warning

stimulus directed attention toward the next stimulus (whether the discriminative stimulus or the ES), both the facilitation and the augmented inhibition are consonant with predictions of the attentional model which I have proposed.

The next experiment attempted to determine the contribution of attention to reflex amplitude by the use of an RT task. In the first of two conditions, subjects received high and low frequency tone prestimuli, followed by an airpuff ES, which was in turn followed by a light which served as an imperative stimulus (IS). They were instructed to respond as quickly as possible to the IS by simultaneously pressing switches held in the left and right hands. In the second condition, subjects were instructed to respond with one hand when the PS was high and with the other when the PS was low. This was intended to provide the PS with task-relevant information in the latter condition, thus directing attention to the PS and increasing its inhibitory potency. Since the stimulus configuration was identical in the two conditions, any difference in the amount of inhibition could be ascribed more confidently to attention, or at least to the experimental instructions.

Pilot testing with young subjects revealed no difference in the amount of inhibition between the two conditions. However, the overall amount of inhibition was much greater than in the previous two experiments. In Experiments 1 and 2, the ES produced a reduction of

approximately 10% to 30%, depending upon stimulus configuration. This pilot project resulted in inhibition of roughly 65%, or double the previous inhibition.

This work was followed by three additional pilot studies in order to define the stimulus conditions necessary to produce this effect. In the first of these, the effect of the RT task itself was compared to a no-RT task condition. In one of two counterbalanced, within-subject conditions, subjects were required to respond to an IS, which followed the ES by five seconds, by pressing a button. In the other condition, no IS was presented and no response was required. In both conditions, subjects received ES-alone trials and trials in which the PS preceded the ES. When the no-response condition preceded the response condition, there was almost three times greater inhibition in the response condition. However, if the response condition was experienced first, there was no difference between the conditions. A comparison between the order groups on the first condition experienced (RT vs. no-RT) revealed approximately five times greater inhibition in the RT group. These results suggested a residual effect from the response condition. This pattern could be explained by either a slowly subsiding arousal produced by the RT task or by the inability of the subjects to suppress the direction of attention toward the PS.



In an attempt to more evenly distribute the residual effect of response condition, the next pilot project used six alternating blocks of nine trials instead of two blocks of 27 trials, as in the previous investigation. With this manipulation, slightly more inhibition occurred in the response condition (26% vs. 31%).

In both of these pilot studies, the PS and/or the ES could serve as an adequate warning stimulus for the required response since the temporal interval between them was always fixed. The final pilot project was an attempt to remove any warning or signal value from the PS and the ES by eliminating any predictive relationship between these stimuli and the IS. The investigation was comprised of two conditions, presented in two blocks of 18 trials. In the first condition, the IS was not presented and no response was required. In the second condition, an IS was presented every 23 secs, while the intertrial interval varied from 20 to 40 secs. Thus the PS and ES provided no information regarding the time until the next required response. The difference in the amount of inhibition between the two conditions was negligible (25% vs. 28%). This seemed to imply that the RT task per se was not sufficient to augment the inhibitory process.

These pilot projects suggested that the inclusion of an RT task within the reflex modification procedure greatly increased the amount of inhibition produced by the PS. The

reason for this effect is not at all apparent. As indicated by Ison and Ashkenazie (1980), it could be due either to generalized arousal or to a manipulation of attention due to the signal value of the PS and ES in predicting the imminent IS.

The third experiment in this dissertation was accordingly designed in an attempt to separate these possibilities. All subjects received three conditions presented in three homogeneous trial blocks. The first condition consisted of ES-alone control trials and trials with a preceding PS. The second condition included an IS, which was temporally independent of the ES and PS. The third condition was arranged so that the IS followed the ES by a constant interval. If the ES or the PS-ES pair serves as an attended signal for the imminent IS, inhibition should be greatest in the third condition. On prepulse trials, the attentional model would predict augmented inhibition due to increased attention directed toward the PS by virtue of its value in predicting the IS. On ES-alone trials, the ES fulfills this function and therefore, these responses should be augmented. Both of these phenomena would contribute to greater inhibition. If the effect is due to arousal, Conditions 2 and 3 should produce equally greater inhibition than Condition 1. If both arousal and attention are contributing, Conditions 1, 2, and 3 should produce increasing amounts of inhibition. Finally, due to the

decline with age in the efficiency of effortful attention, any effects due to this variable should be more pronounced in young than in elderly subjects.

### Method

#### Subjects

There were 24 young and 24 old subjects in this experiment. Due to difficulty in locating elderly males, both the old and young groups were comprised of six males and 18 females. The young subjects ranged in age from 17 to 23 years (mean=19.4). The old subjects ranged in age from 57 to 82 years (mean=69.4). Two additional young subjects were eliminated from the analyses, one for procedural error and one for drowsiness. One elderly subject was eliminated for producing fewer than three scoreable eyeblink responses per condition.

#### Procedure

Stimuli in this experiment consisted of a tone PS, an airpuff ES, and a red LED which served as the IS. The PS was presented for 50 msecs at a frequency of 1000 Hz and an intensity of 70 dB. Rise/fall times were set at 5 msecs. The ES was delivered at an intensity of 80 mm Hg for 50 msecs. The ISI between PS and ES was set at 120 msecs, measured from offset to onset.

There were three conditions in this experiment. In Condition 1, subjects received only the PS-ES combination

and ES-alone control trials. In Condition 2, subjects received the PS and ES, but in addition, the IS was presented and subjects responded to it by pressing a thumb switch held in the left hand. Three randomly occurring IS-to-IS intervals were employed, 17, 30, and 43 secs (mean=30 secs). In Condition 3, the ES was followed by the IS after a constant interval of 5 secs. In each condition, subjects received six control trials and six prepulsed trials arranged in random order. The intertrial interval ranged from 20 to 40 secs with a mean of 30 secs. These intervals resulted in the presentation of 12 imperative stimuli to which responses were required in both Conditions 2 and 3. Condition order was counterbalanced within sex and age.

After being connected to the recording equipment, subjects received five airpuff stimuli for the purpose of adjusting gain settings and to familiarize the subjects with the stimulus. Instructions were then given at the beginning of each condition. For Condition 1, subjects were instructed to simply sit quietly and stay awake. For Condition 2, subjects were told that the red light would occur at "random times" throughout the condition and that they were to respond as quickly as possible by pressing the switch. It was stressed that the occurrence of the IS was unrelated to ES presentation. For Condition 3, subjects were told that the IS would "follow predictably" after the ES. All other instructions were identical to Condition 2. In Conditions 2

and 3, subjects were provided with a Lafayette Model 54417 clock/counter which displayed their reaction times and were encouraged to continually better their times. Reaction times were also measured outside the experimental room with an Iconix Model 6225 clock/counter and recorded to the nearest msec.

## Results

### Reaction time

Median reaction times for each subject from Conditions 2 and 3 were analyzed with a 2 AGE X 2 Condition analysis of variance. Results indicated a significant age difference ( $F(1,46)=11.41$ ,  $p=.0015$ ) and a strong effect of Condition ( $F(1,93)=73.42$ ,  $p<.0001$ ). The AGE X Condition interaction was not significant. Neither of these effects is particularly surprising. The elderly were slower in their responses and the responses of both groups were faster in Condition 3. This implies that the ES and the PS-ES combination were indeed functioning as warning stimuli in Condition 3.

### Eyeblink

For each of the three conditions, each subject's mean control response was subtracted from the response on the prepulsed trials and corrected for gain. These gain-difference scores were first analyzed with a 2 AGE X 3 Condition X 6 Order analysis of variance. (Mean responses

are depicted in Figure 5.) The only significant contrast was a main effect of Condition ( $F(2,72)=4.53$ ,  $p=.0141$ ).

For exploratory purposes, the data were next analyzed within each age group with one-way analyses of variance testing the three conditions. This contrast was not significant in the old subjects, but did reach significance in the young subjects ( $F(2,46)=5.09$ ,  $p=.0101$ ). A followup Newman-Keuls analysis revealed that Conditions 2 and 3 were reliably different from Condition 1 but not from each other. Thus the incorporation of an RT task into the reflex modification procedure greatly increased the amount of inhibition in young but not in old subjects.

#### Heart rate

As in the previous experiments, HR was measured for one second before and for five seconds after the airpuff ES. These responses are depicted in Figure 6 for the young subjects and in Figure 7 for the elderly subjects.

Data were initially analyzed with a 2 AGE X 2 prepulse versus control (PC) X 3 RT condition (COND) X 6 SEC analysis of variance. This analysis revealed several significant effects. The significant SEC effect ( $F(5,220)=8.35$ ,  $p<.0001$ ) indicated that there was a reliable response. The COND X SEC ( $F(10,440)=4.52$ ,  $p<.0001$ ) and PC X SEC ( $F(5,220)=2.40$ ,  $p=.0383$ ) effects indicated that the shape of the response was a function of both the RT task conditions and the presence of a PS. Finally, AGE interacted significantly with

PC ( $F(1,44)=5.27$ ,  $p=.0265$ ) and SEC ( $F(5,220)=5.33$ ,  $p=.0001$ ), indicating that the PS affected HR differently in the two age groups and that the response shape was also different for young and old subjects. (Previous analyses indicated that treatment order was not an important factor in either group.)

Based upon the AGE interactions, the data were analyzed separately for young and old subjects with 2 PC X 3 CCND X 6 SEC analyses of variance with orthogonal trend decomposition. The elderly subjects revealed a significant SEC effect ( $F(5,110)=2.71$ ,  $p=.0237$ ) which was composed of significant quadratic ( $F(1,22)=5.29$ ,  $p=.0313$ ) and cubic ( $F(1,22)=9.93$ ,  $p=.0046$ ) components. In addition, the CCND effect was significant ( $F(2,44)=6.53$ ,  $p=.0033$ ), as was the COND X quadratic SEC effect ( $F(2,44)=4.33$ ,  $p<.05$ ). The latter effect provided weak evidence that the HR response was affected by the RT task condition. Notably, none of the effects involving the PS reached significance. The young subjects also evidenced a significant SEC effect ( $F(5,110)=7.99$ ,  $p<.0001$ ). This was composed of a strong cubic trend ( $F(1,22)=48.77$ ,  $p<.0001$ ) and smaller quadratic ( $F(1,22)=8.24$ ,  $p=.0089$ ) and quintic ( $F(1,22)=8.11$ ,  $p=.0094$ ) components. The significant COND X SEC effect ( $F(10,220)=3.55$ ,  $p=.0002$ ) was composed of a significant CCND X quadratic SEC effect ( $F(2,44)=5.69$ ,  $p<.01$ ), indicating an effect of RT condition on the HR response. The significant

PC X SEC effect ( $F(5,110)=2.65$ ,  $p=.0264$ ) was composed of significant PC X quadratic SEC ( $F(1,22)=10.11$ ,  $p=.0043$ ) and PC X cubic SEC ( $F(1,22)=4.91$ ,  $p=.0373$ ) effects, implying that the HR response was affected by the PS.

There are several points to be made on the basis of these analyses: 1) the HR response of the young subjects was again modified by the PS while that of the elderly was not, 2) the HR response of the young was robustly affected by the RT task conditions, while that of the elderly was affected weakly, if at all, 3) the overall HR level was affected by the inclusion of the RT task in the elderly but not in the young subjects, and 4) the lack of significant PC X COND X SEC effects in either group implies that the effect of the PS upon the HR response was not a function of the RT task conditions.

In order to explore the effects upon the decelerative and accelerative components of the elicited HR response in more detail, the points of maximum deceleration (first poststimulus second) and acceleration (third poststimulus second) were analyzed by 3 Condition X 2 PC analyses of variance within the two age groups. The results confirmed earlier conclusions in that the old subjects produced an effect of Condition for both the decelerative ( $F(2,44)=6.52$ ,  $p=.0033$ ) and the accelerative ( $F(2,44)=5.89$ ,  $p=.0054$ ) components of the response, whereas the PS had no effect upon responding in this group. In contrast, the young



subjects showed no effect of Condition (indicating no differences across condition in HR level), but reliable effects due to the PS on the magnitude of the deceleration ( $F(1,22)=17.24$ ,  $p=.0004$ ) and, to a lesser extent, upon the acceleration ( $F(1,22)=5.77$ ,  $p=.0252$ ). However, unlike previous findings, the effect of the PS upon the accelerative component was to produce a diminution rather than an augmentation of this portion of the elicited HR response.

### Conclusions

The results of this experiment support the conclusion that reflex modification is profoundly affected by the inclusion of a reaction time task in young subjects but not in the elderly. As predicted, the effect upon the eyeblink was to increase the inhibitory effect of the PS. Although for the HR response the effect of Condition did not interact with the presence or absence of the PS, perusal of Figure 6 suggests that the effect is one of augmenting the decelerative component of the HR response, moreso in the two RT conditions.

The RT conditions produced effects upon the responses which were greater than the no-RT condition and not different from each other. This clearly supports the configuration advanced in the introduction to this experiment as support for some type of arousal operating

upon the reflex modification process. It is conceivable that an elevated state of central nervous system activity was produced by the challenging RT task and that this state augmented the inhibition of elicited eyeblinks and the modification of the elicited HR responses.

There are at least two reasons to question this conclusion. As Lacey (Lacey, 1967; Lacey, Kagan, Lacey, and Moss, 1963) has indicated, arousal is not an unidimensional process. Various autonomic and central responses do not covary across experimental conditions. In addition, the effect of a PS has been found to be independent of various manipulations (e.g. changes in ES intensity) which result in increases or decreases in the amplitude of the elicited response (see Hoffman and Ison, 1980 for a discussion). It seems reasonable to suppose that one effect of arousal would be to determine, at least in part, the amplitude of the elicited response. Therefore, if the amount of inhibition is independent of the amplitude of the response, it is unlikely that arousal would affect the inhibition process. Secondly, in this experiment the elderly subjects demonstrated a significantly elevated HR level in the two RT conditions, suggesting an increased arousal, yet the eyeblink modification process was unaffected. In contrast, the young subjects, who did yield the predicted effects upon the eyeblink and HR responses, showed no effects of Condition upon HR level. The mean HR levels for the young subjects in

Conditions 1, 2, and 3 were 75.9 beats per minute (bpm), 76.6 bpm, and 76.6 bpm respectively, while corresponding values for the old subjects were 74.9 bpm, 76.2 bpm, and 76.8 bpm. Thus the old subjects had a range of 1.9 bpm across conditions compared to .7 bpm for the young subjects. If HR level is a valid index of arousal, this finding argues against the possibility that these results are due to arousal produced by the RT task.

Boelhouwer (1980) elicited eyeblinks at various times during a three second foreperiod of a reaction time procedure. He found effects upon both the monosynaptic and polysynaptic components of the neural activity responsible for the eyeblink. These components varied in amplitude as a function of the time intervening between the warning stimulus and the presentation of the ES. Unless it is hypothesized that arousal can fluctuate several times during a three second foreperiod, another process is required to explain these results.

To reiterate, DelPezzo and Hoffman (1980) were able to increase or decrease the inhibitory effect of a particular PS by simply instructing subjects to attend or ignore the stimulus. The findings reported here suggest that a similar process may be operating. It is conceivable that when subjects await an imperative stimulus to which a response is required, they become more attentive to all stimulation. That the young subjects are more able to direct this

effortful attention is further supported by the HR responses depicted in Figures 6 and 7. The young subjects exhibited a large HR deceleration between seconds three and five in the contingent RT condition (Condition 3). This deceleration is commonly found in constant-foreperiod RT tasks. (In this case, the IS was presented at the fifth second.) The deceleration was not nearly as evident in the elderly subjects, a finding consistent with Thompson and Nowlin (1973) and Morris and Thompson (1969). If it is true, as suggested by Lacey (Lacey, 1967; Lacey, Kagan, Lacey, and Moss, 1963; Lacey and Lacey, 1974), that HR deceleration facilitates attention toward the sensory environment, these data suggest that the elderly are less able to accomplish this effortful direction of attention.

## CHAPTER 6

### EXPERIMENT 4

As previously indicated, virtually any change in the sensory environment will function as an inhibitory PS, given the appropriate temporal relationships. Stimuli which have been employed to date include tones (e.g. Graham and Murray, 1977), lights (e.g. Reiter and Ison, 1977), shocks (e.g. Pinckney, 1976), noise offset (e.g. Stitt, Hoffman, and Marsh, 1973), and a shift in the frequency spectrum of broad-band noise (e.g. Marsh, Hoffman, Stitt, and Schwartz, 1975). In addition to these stimuli, Ison (personal communication, 1980) has found that a discrete gap in a continuous noise background will also serve to inhibit whole-body startle in rats.

The experiment to follow was designed to test Botwinick's (1978) stimulus persistence hypothesis by using a gap in a continuous tone as a PS. Botwinick has proposed that the older central nervous system needs a greater amount of time in order to "clear" a stimulus, and that this increased stimulus persistence results in differential performance on a number of perceptual tasks, including

reduced flicker fusion thresholds (Weale, 1965) and click fusion thresholds (Weiss, 1963), and greater exposure durations when identifying tachistoscopically presented forms (Salthouse, 1976). In an elegant test of this hypothesis, Kline and Orme-Rogers (1978) found that elderly subjects were better able to identify words when halves of the word forms were presented sequentially. The elderly were able to identify the words at greater ISIs than were the young.

In the following experiment, gaps ranging in duration from 10 to 120 msec were used as prestimuli and three hypotheses were tested. (Psychophysical research has indicated that gaps as small as 5 msec can be reliably detected in tones of similar frequency and intensity to those employed here. See for example Plomp, 1964 and Perrott and Williams, 1971.) First, it was hypothesized that the gaps would effectively inhibit the elicited reflexes. Secondly, drawing upon the proposed attentional model, it was predicted that the amount of inhibition would increase with PS duration, as in Experiment 1. Finally, based upon Botwinick's stimulus persistence hypothesis, it was expected that young subjects would demonstrate significant inhibition at smaller gap durations than elderly subjects.

## Method

### Subjects

Young subjects in this experiment consisted of 12 females and four males, ranging in age from 18 to 24 years (mean=19.4). There were also 12 elderly females and four elderly males, ranging in age from 61 to 78 years (mean=70.0). One young subject and two elderly subjects were eliminated from the analyses for procedural error and one additional elderly subject was eliminated for producing fewer than three scoreable eyeblink responses per condition.

### Procedure

After the subject was connected to the recording equipment and the door to the experimental chamber was closed, a 70 dB, 1000 Hz tone was turned on and remained on until the end of the session. None of the subjects reported this tone to be uncomfortable when queried subsequent to testing. As in previous experiments, the ES was a 50 msec airpuff presented at an intensity of 80 mm Hg. On prepulsed trials, a gap in the continuous tone was presented at an ISI of 120 msec (measured from gap offset to ES onset). Gap durations were 10, 20, 40, 80, and 120 msec. Rise/fall times were set at 1 msec instead of the usual 5 msec so as not to obscure the shorter duration gaps. No switching transients were easily perceptible. The five PS durations plus the ES-alone control condition were arranged into a 6 X

6 latin square. For the purpose of counterbalancing orders of conditions, subjects started at different rows of the latin square and proceeded through the entire square for a total of 36 trials, six in each condition. Intertrial intervals ranged from 20 to 40 secs with a mean of 30 secs.

## Results

### Eyeblink

Data were averaged within each condition and subject and corrected for the gain setting. The mean control response was then subtracted from each of the prepulsed responses. These gain-corrected difference scores comprised the data for the analyses and are depicted in Figure 8.

Data were first analyzed with a 2 AGE X 5 PS duration analysis of variance with orthogonal trend decomposition. There was a significant effect of PS duration ( $F(4,120)=5.09$ ,  $p=.0008$ ) which was comprised of significant quadratic ( $F(1,30)=8.24$ ,  $p=.0074$ ) and linear ( $F(1,30)=7.52$ ,  $p=.0102$ ) components. In addition, the linear trend interacted significantly with AGE ( $F(1,30)=4.63$ ,  $p=.0397$ ). These results implied that the gap served as an effective PS and that the amount of inhibition varied as a function of PS duration. The AGE X linear PS duration contrast indicated that the shape of the function was different for the two age groups. Consequently, the data were analyzed separately within the age groups with a 5 PS duration analysis of



variance with orthogonal trend decomposition. As implied by Figure 8, the young subjects evidenced a significant quadratic function ( $F(1,15)=4.56$ ,  $p=.0496$ ) whereas the elderly curve was linear across PS duration ( $F(1,15)=13.22$ ,  $p=.0024$ ).

In order to specifically test the hypothesis that the younger subjects would show inhibition at smaller PS durations than the elderly, Dunnett's followup test (Kirk, 1968) was used to test for differences between the control response and each of the prepulsed responses. This test indicated that all of the prepulsed responses were significantly smaller than the control response in the young subjects. In the elderly subjects, all were different except the 10 msec PS.

#### Heart rate

Heart rate was measured for 1 sec before and for 5 secs after the airpuff ES. The responses were averaged within each condition and subject. The mean responses are depicted in Figure 9 for the young subjects and in Figure 10 for the elderly subjects. Data were initially analyzed with a 2 AGE X 6 Condition X 6 Second (SEC) analysis of variance. The only effects to reach significance were the SEC effect ( $F(5,150)=7.04$ ,  $p<.0001$ ) and the AGE X SEC interaction ( $F(5,150)=5.93$ ,  $p<.0001$ ), indicating a significance response which differed in shape across the age groups.

Orthogonal trend analyses within the two age groups indicated significant quadratic ( $F(1,15)=13.29$ ,  $p=.0024$ ) and cubic ( $F(1,15)=10.44$ ,  $p=.0056$ ) components of the SEC effect in the old group, as well as a significant quintic component ( $F(1,15)=10.02$ ,  $p=.0064$ ), though this component accounted for much less variance than the other two. The young subjects also evidenced quadratic ( $F=8.77$ ,  $p=.0097$ ) and cubic ( $F=11.48$ ,  $p=.0041$ ) SEC trends.

Notably, there was an absence of effects involving stimulus condition upon the shape of the HR response, though it appears in Figures 9 and 10 that the PS tended to accentuate the initial decelerative component, as in previous experiments. Perusal of Figure 9 also indicates that the PS seemed to reduce the magnitude of the accelerative component of the response in the young subjects. In a post-hoc attempt to assess these effects, the first and third poststimulus seconds were analyzed within the age groups with one-way analyses of variance over the six stimulus conditions. The results were consistent with the preceding analyses in showing no effect of condition upon either the deceleration or acceleration in either age group.

### Conclusions

These results are consistent with Berg's (1973) conclusion that the eyeblink and HR responses represent

different components of the startle reflex. This was indicated by the significant effects of the PS upon the eyeblink and the absence of effects upon the elicited HR response.

The attentional model again finds support in these data. The amount of inhibition increased with increasing PS duration with the exception of the longest PS in the young group. The absence of age differences in the amount of inhibition supports the notion that the direction of automatic attentional processes is preserved well into old age.

Finally, Botwinick's (1978) stimulus persistence hypothesis received tentative support from these results. Although the AGE X PS duration contrast was not significant, the followup tests did indicate that the young subjects showed reflex inhibition with smaller duration gaps than the elderly.

## CHAPTER 7 DISCUSSION

The results reported here strongly support the conclusion, proposed by Berg (1973), that the eyeblink and HR components of the elicited startle reflex represent less than perfectly correlated responses. The primary aspect of my results which favors such a conceptualization is the ontogenetic dissociation of the two responses which occurred repeatedly in these experiments. In none of the four experiments did the elderly reveal large effects of a PS upon the elicited HR response, despite consistent eyeblink inhibition. As previously emphasized, this was not due to a lack of HR responsivity in the elderly. Both age groups revealed robust phasic changes in HR subsequent to the eliciting airpuff. It seems evident therefore, that the eyeblink and HR responses reflect semi-independent components of the startle and that the modification of these responses pursue dissimilar developmental courses.

The eyeblink and HR responses were also differentially influenced by the experimental manipulations in this investigation. Restricting attention for the moment to the

young subjects, it is evident that inhibition of the eyeblink by a suitably arranged PS is no guarantee that this prestimulus will affect HR. For example, in Experiment 1, both eyeblink and HR modification were evident. For both responses, the effects were greater for longer duration prestimuli and evidenced a U-shaped function over the range of ISIs investigated. In the third experiment, the inclusion of a reaction time task in the procedure greatly increased the amount of eyeblink modification while affecting the HR response only marginally. Finally, in Experiment 4, the PS had virtually no effect upon the HR response while inhibiting the eyeblink significantly. It remains for future research to elucidate the critical stimulus parameters for differentiation of these startle components.

The literature is inconsistent regarding the exact shape of the elicited HR response. In a review of the HR literature, Graham (1979) concluded that the response was composed of a small, brief acceleration followed by a return to prestimulus HR level. Graham's (1979) conclusions were hampered, however, by the paucity of studies specifically investigating the startle reflex. It was necessary for her to carefully evaluate the stimulus parameters of the studies reviewed and make a decision as to whether or not the stimuli were likely to elicit eyeblink in humans or whole-body startle in laboratory animals. In agreement with Graham (1979), Chalmers and Hoffman (1973) found a HR acceleration

accompanying whole-body startle in rats. Berg (1973), however, found a decelerative response as did Clarkson (1979). In the four experiments reported here, the control response in both age groups was biphasic (and this conclusion was consistently supported by significant cubic trends). The decelerative component reached a nadir at 1 to 2 secs poststimulus and was more variable in magnitude than the acceleration, which peaked at 3 to 4 secs. Developmentally, the accelerative component was less prominent in the elderly subjects, though it was always statistically reliable.

The results of this research have indicated that the effect of a PS upon the elicited HR response is primarily upon the decelerative component of the response. The effect is one of accentuating the magnitude of this deceleration. In some cases, the accelerative component was also altered, but these changes were smaller and less reliable. It is inappropriate to refer to these effects as inhibitory. Unlike the effect upon eyeblink, the PS served to augment various aspects of the HR response. This conclusion is at variance with Chalmers and Hoffman (1973), who found that a PS functioned to reduce the size of a primarily accelerative response. This finding again underscores the conclusion that the eyeblink and HR components of the startle complex are somewhat independent of one another.

The results of the analyses of the eyeblink responses suggest that reflex inhibition can be profitably discussed in terms of the "amplifying" effects of attention. Consistent with predictions of the attentional model which I have proposed, manipulations which rendered the PS more salient, or attention-getting, also served to increase its inhibitory potency. This was true whether the manipulation was to increase the duration of a tone PS or a gap in a continuous tone. The latter finding is important in that it indicates that the results of Experiment 1 were not simply due to increasing the total energy of the PS. This strengthens the argument that these effects are due, at least in part, to attentional as opposed to basic, energy-related neurophysiological processes.

The failure to affect the amount of inhibition in Experiment 2 by instructing subjects to count a rare PS is puzzling. DelPezzo and Hoffman (1980) were able to produce changes in the amount of inhibition with a manipulation which seems at least as subtle as the one used in Experiment 2. They were able to increase or decrease the amount of inhibition simply by instructing their subjects to attend or ignore a particular PS. I can only speculate that the difference between the 1000 Hz and the 500 Hz was so salient, and the number of tones to be counted so small (five), that the task was too easy to sufficiently engage effortful attentional processes to any degree in Experiment 3.

The developmental perspective taken in this investigation was useful not only in describing age differences in reflex modification (indeed, in demonstrating that the elderly will produce the phenomenon at all), but also in elucidating the contribution of attention to the reflex inhibition process. In drawing upon a literature independent of the history of reflex modification (i.e. age differences in effortful versus automatic attention), it was possible to add to existing knowledge regarding both reflex modification and the adult development of attention. This investigation supported the position advanced by Hoyer and Plude (1980) that the elderly maintain their automatic attentional abilities to a greater extent than their effortful attentional processes. The distinction between automatic and effortful processing is not clear-cut and is usually made at the empirical level. For example, Plude and Hoyer (1980) utilized a card-sorting task in which a target letter was imbedded in zero to eight distractor letters. When the letters to be searched for were unchanging, no age differences in performance were found. However, when the target letters changed over trials, consistent age decrements were found. According to the authors, the unchanging set allowed for the development of automatic search strategies whereas the changing set required active retrieval and comparison.



One criterion for deciding whether or not a skill is automatic was proposed by LaBerge and Samuels (1974). According to these researchers, if a task can be accomplished while attention is directed elsewhere, it involves automatic processes. In their analysis of reading skills, they emphasized repetition as necessary for the development of automaticity. For example, with practice a reader is able to recognize words and their meanings with very little effort. However, the beginning reader must make a conscious effort to identify individual letters and their associated sounds, combine those letters into words, and remember the meaning ascribed to that particular constellation of letters and sounds. Hasher and Zacks (1979) defined automatic processes as not requiring awareness of their use and as not benefitting from practice or feedback. The utilization of these processes was seen as outside the bounds of voluntary control. Effortful processes were described as requiring voluntary use and as benefitting from practice. Finally, effortful, but not automatic, processes limit one's ability to carry out other tasks. It seems reasonable to suppose that the PS duration effects evident in Experiments 1 and 4 would obtain when attention was directed elsewhere, though it remains for future research to confirm this speculation. It seems unlikely that the reaction time task in Experiment 3 could be performed as successfully if attention was allocated to

another task. The absence of age differences in those experiments purporting to manipulate automatic (Experiments 1 and 4) coupled with the significant age differences when effortful attention was supposedly varied (Experiment 3) lends greater credence to the contention that attention was in fact being manipulated. Extensive training of the reaction time skills required in Experiment 3 would presumably lead to automaticity and it could be predicted that this training would decrease the age differences in reflex inhibition seen in this experiment. In addition, since involuntary responses were measured, age differences in response criteria, cautiousness, or task-specific abilities are implausible explanations for these results.

The fourth experiment demonstrated that the reflex inhibition procedure can be used to investigate attentional/perceptual phenomena. Botwinick's (1978) stimulus persistence hypothesis received tentative support in that the young subjects revealed significant inhibition with a smaller gap PS than the elderly. Evaluations of the stimulus persistence model with other than visual, tachistoscopic methods fills a void which has been previously indicated (Kline and Scheiber, 1980). As stated in Chapter 6, however, the AGE X DURATION interaction was not significant. Followup tests provided weak evidence in favor of the hypothesis, though additional research is certainly warranted.

Birren's (1974) calculator model was not supported by the results of Experiment 1. If indeed, the elderly nervous system is running more slowly, the reflex inhibition process should also occur more slowly. This would cause a shift in the elderly toward greater effective ISIs between PS and ES (similar to the results of visual masking studies). This was not found. The ISIs employed were chosen from a wide range, however, and it will be necessary to more precisely define the ISI functions within age groups before strong conclusions regarding the speed of the inhibition can be made. Also, Birren's (1974) model has emphasized that this slowing primarily involves voluntary decision-making rather than sensory or motor processes. The involuntary responses investigated in the present research may not be directly analogous to those supporting Birren's model.

This project finally indicates some considerations which should be addressed by future research in reflex modification. First, it is important to consider the attentional state of the subject when assessing the effects of various stimulus condition upon the inhibition process. This includes instructions to the subjects and any tasks to be performed. Second, it is evident that the startle reflex is not a unitary process, that at least two components of the reflex, HR and eyeblink, do not covary perfectly in response to changes in stimulus configuration. Thirdly, the investigation of reflex modification and other

psychophysiological response systems can benefit both substantively and theoretically from a developmental approach to investigation.

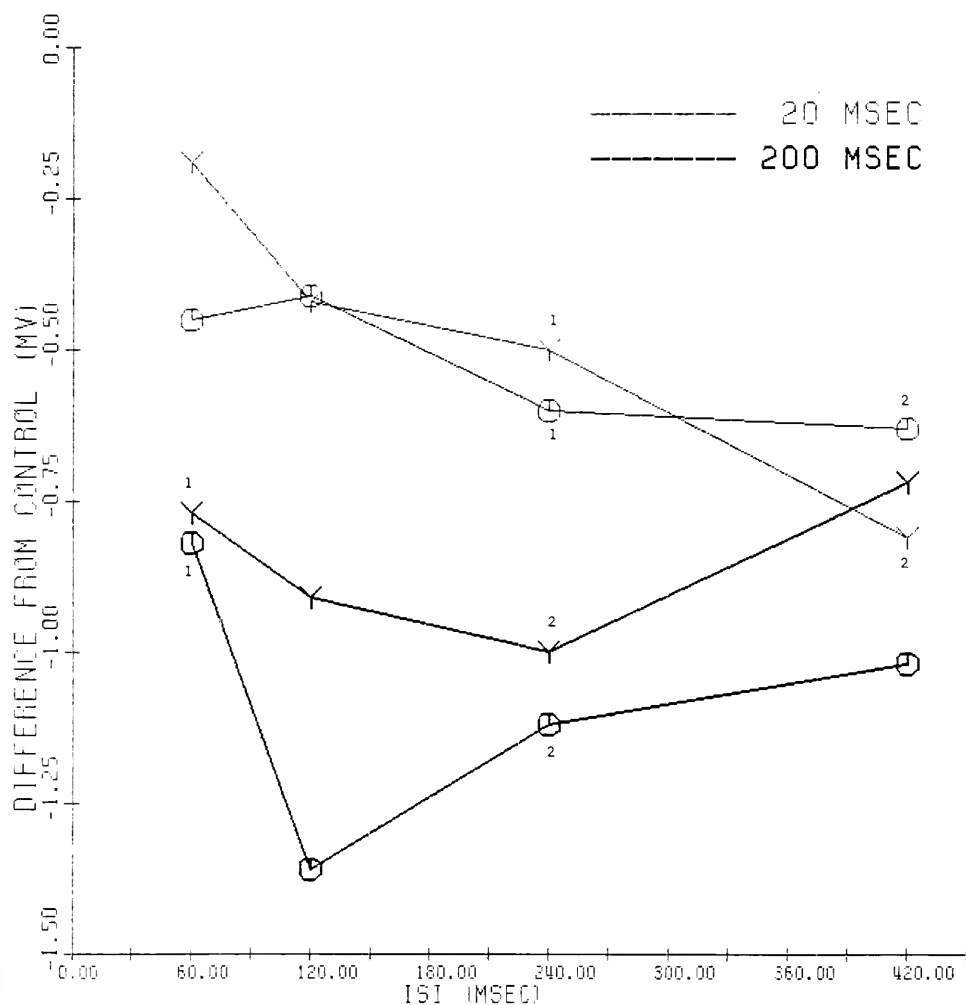


Figure 1. Experiment 1: Mean eyeblink responses from young (Y) and old (O) subjects. 1 indicates 260 msec SOA, 2 indicates 440 msec SOA.

## ISI

- \*—\* 60 MSEC
- X—X 120 MSEC
- +—+ 240 MSEC
- 420 MSEC
- Z—Z CONTROL

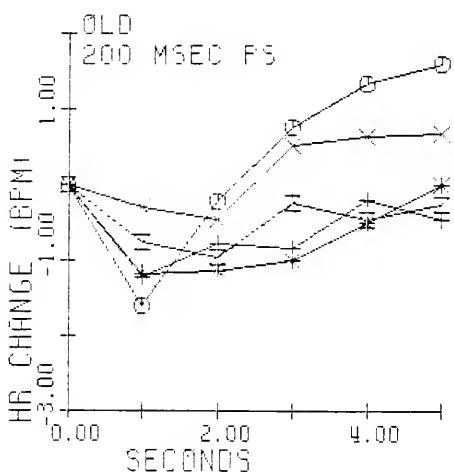
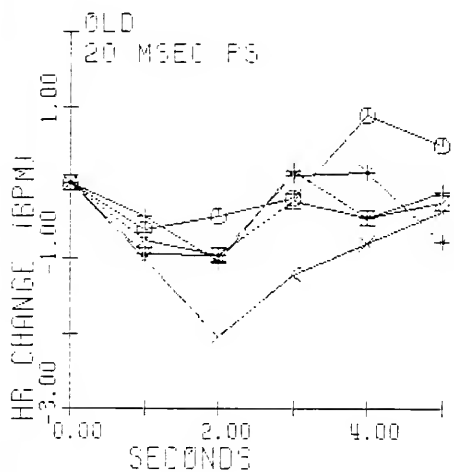
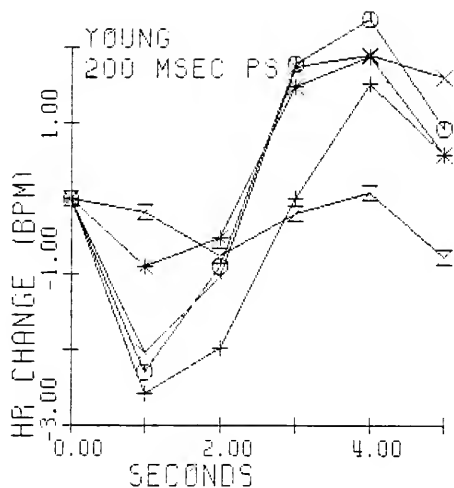
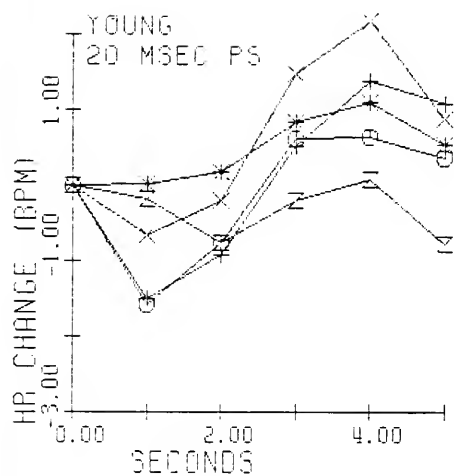


Figure 2. Experiment 1: Mean heart rate responses. Control responses are depicted with both PS durations for comparison.

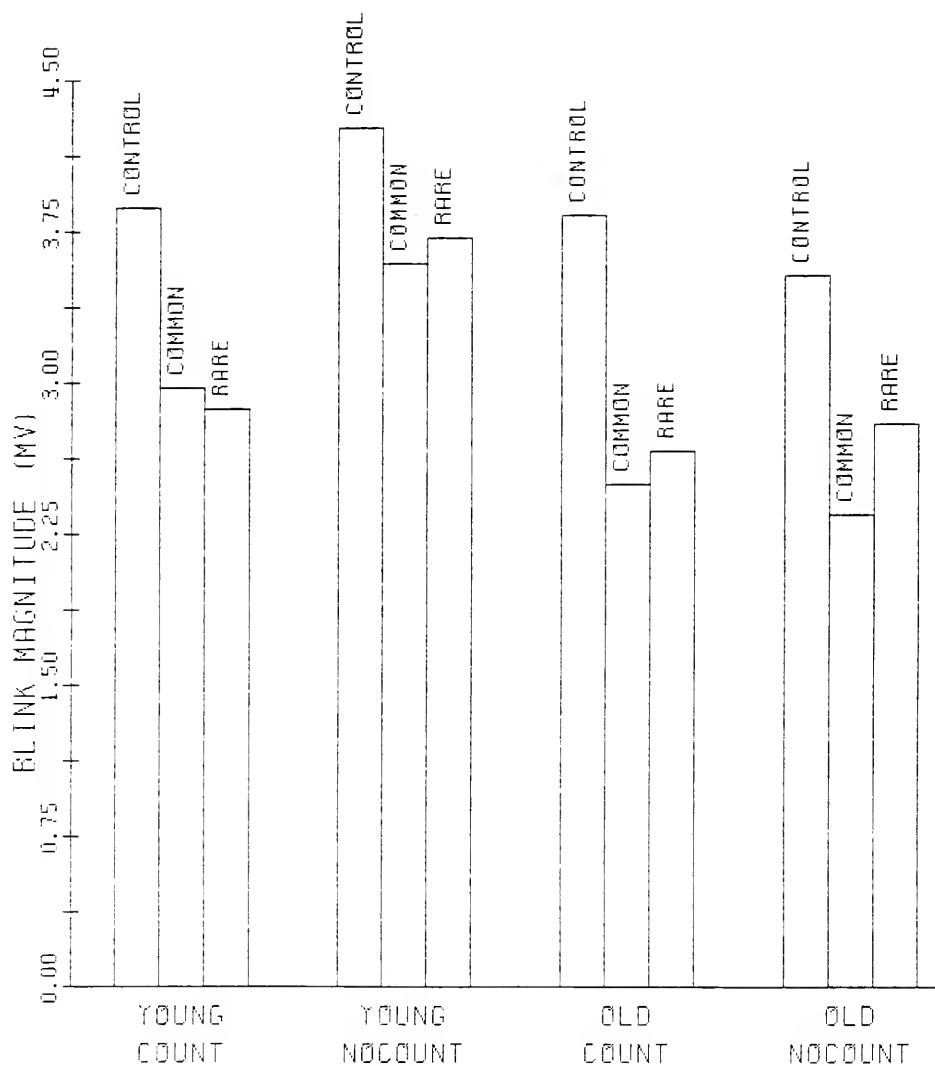


Figure 3. Experiment 2: Mean eyeblink responses.

Z — Z CONTROL  
 O — O COMMON  
 X — X RARE

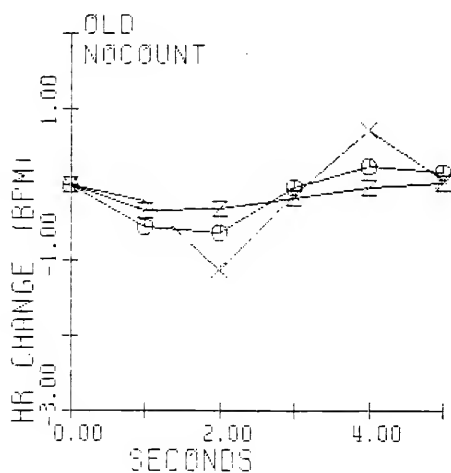
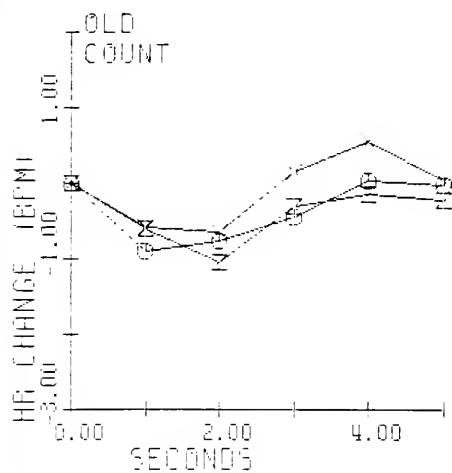
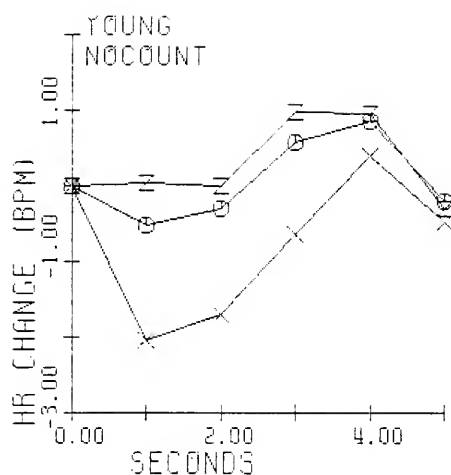
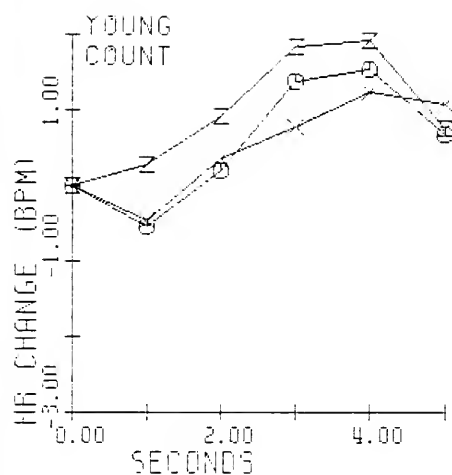


Figure 4. Experiment 2: Mean heart rate responses.



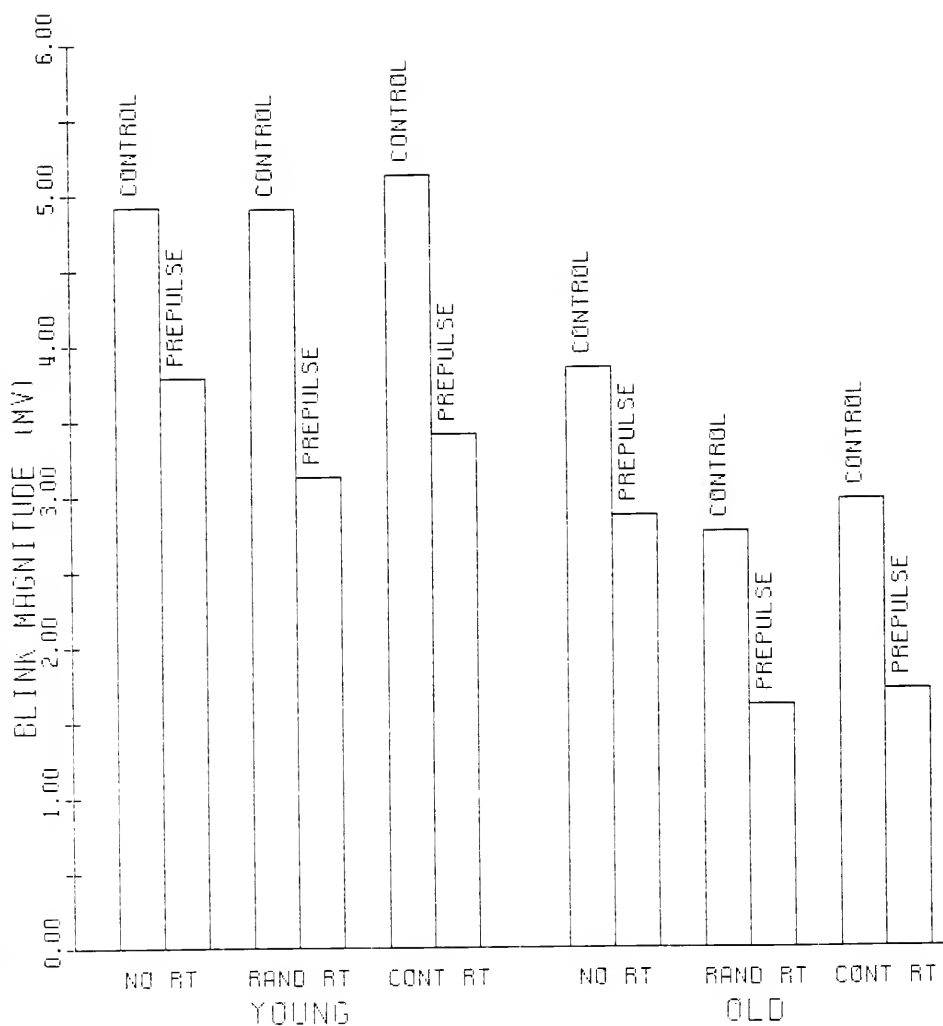


Figure 5. Experiment 3: Mean eyeblink responses from the reaction time (RT) conditions; NO RT, randomly presented (RAND) RT, and contingently presented (CONT) RT.

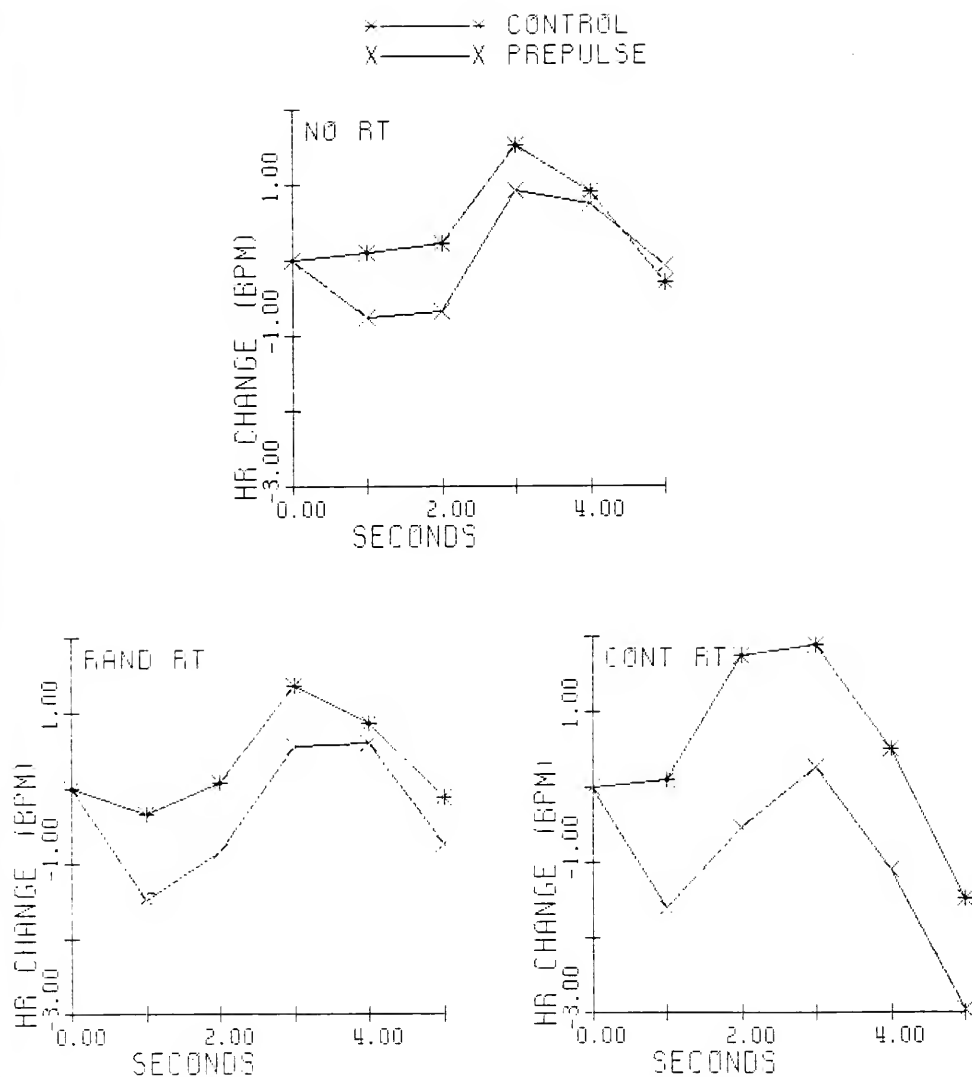


Figure 6. Experiment 3: Mean heart rate responses from the young subjects from the NO reaction time (RT), randomly presented (RAND) RT, and contingently presented (CONT) RT conditions.

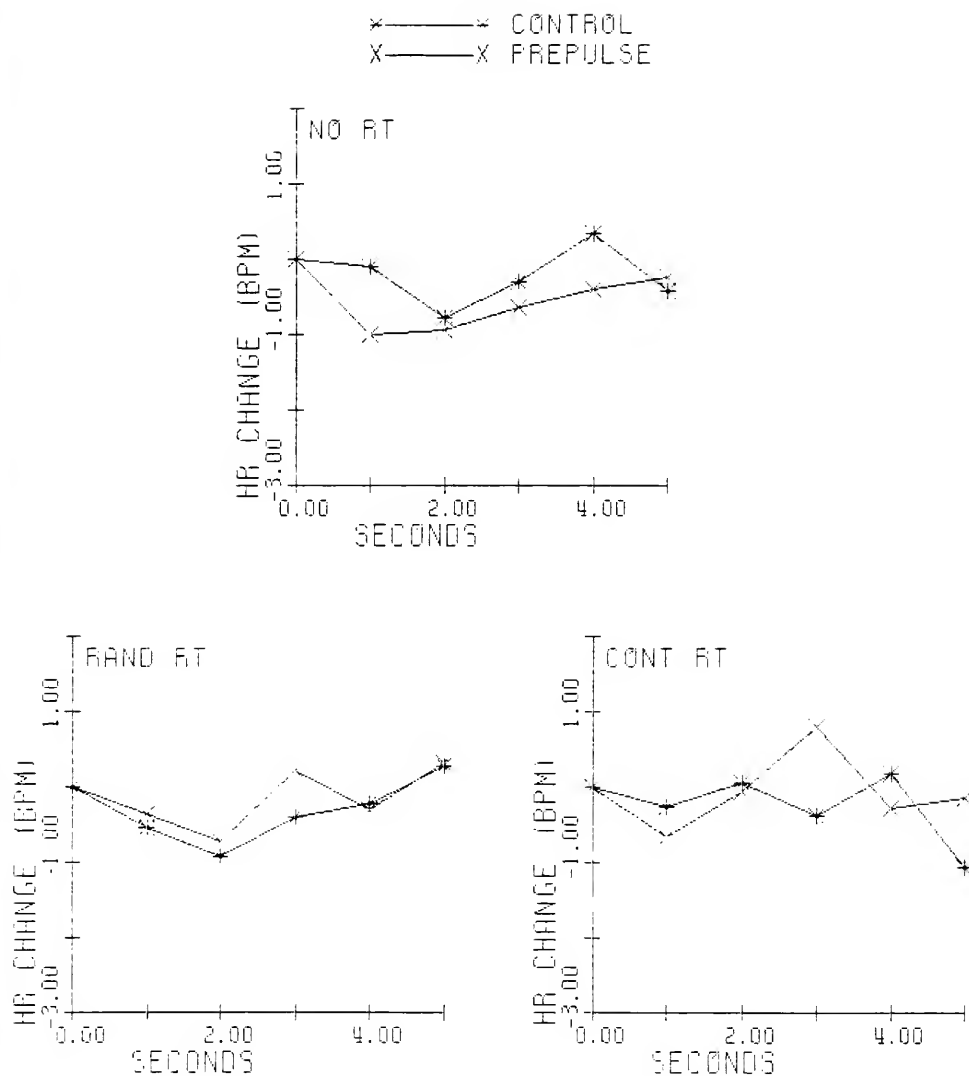


Figure 7. Experiment 3: Mean heart rate responses from the old subjects from the NO reaction time (RT), randomly presented (RAND) RT, and contingently presented (CONT) RT conditions.

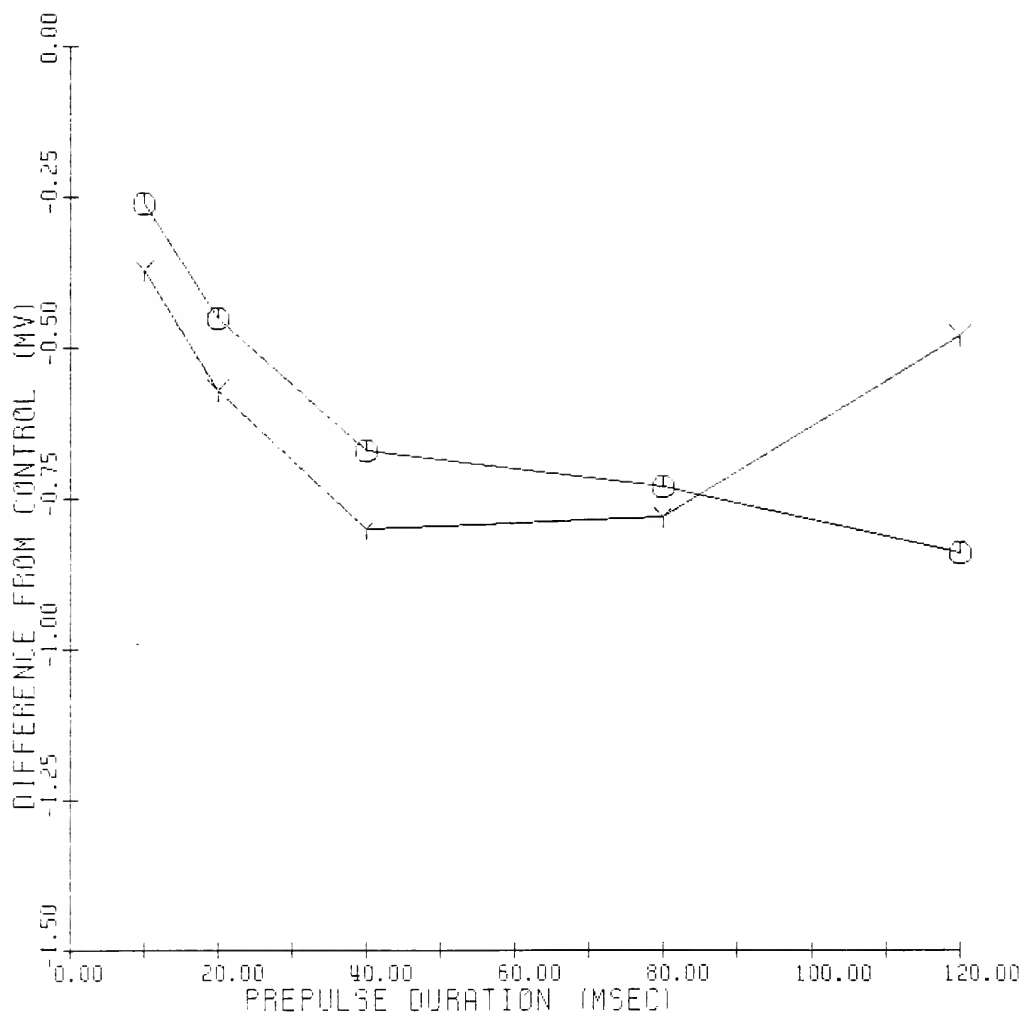


Figure 8. Experiment 4: Mean eyeblink responses from young (Y) and old (O) subjects.

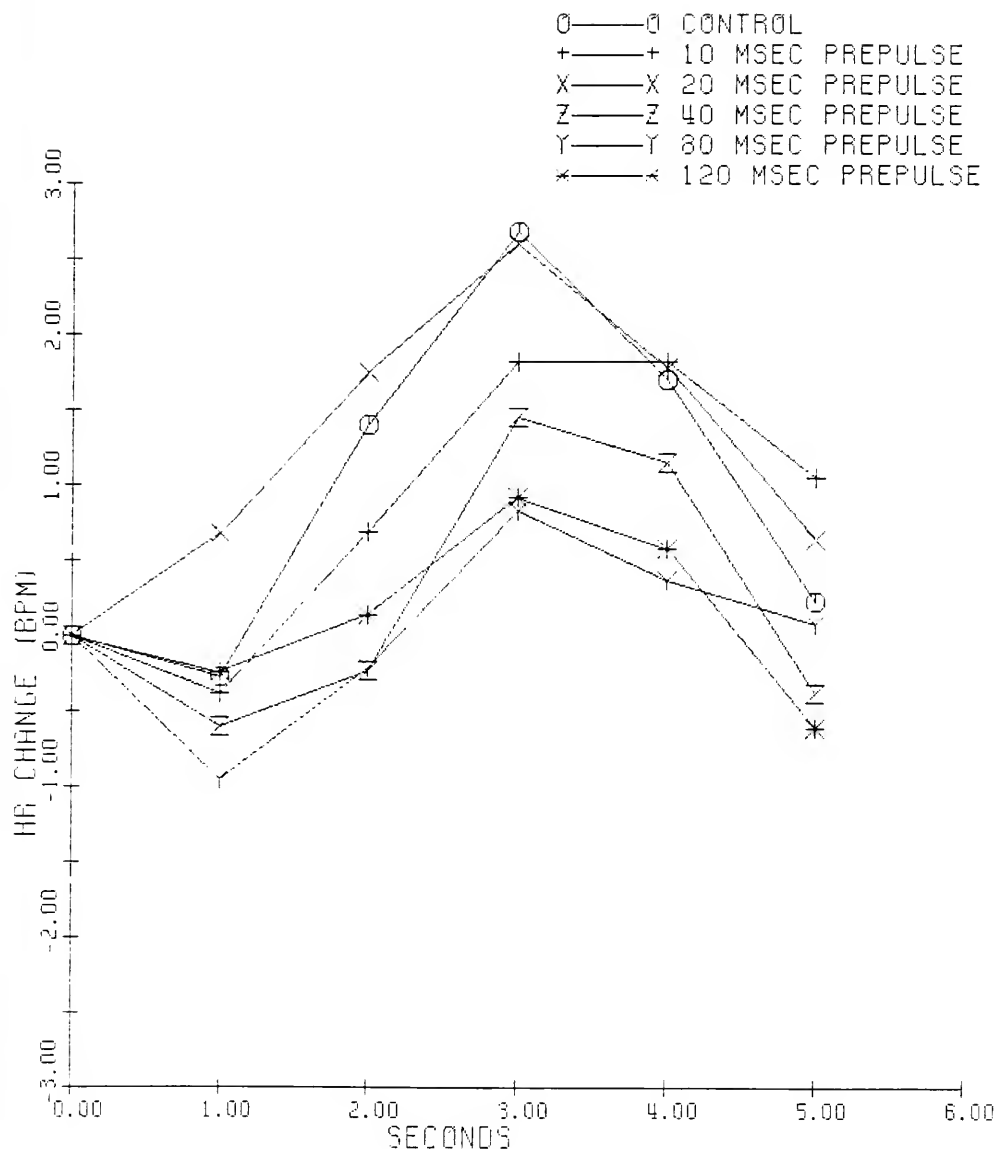


Figure 9. Experiment 4: Mean heart rate responses from young subjects.

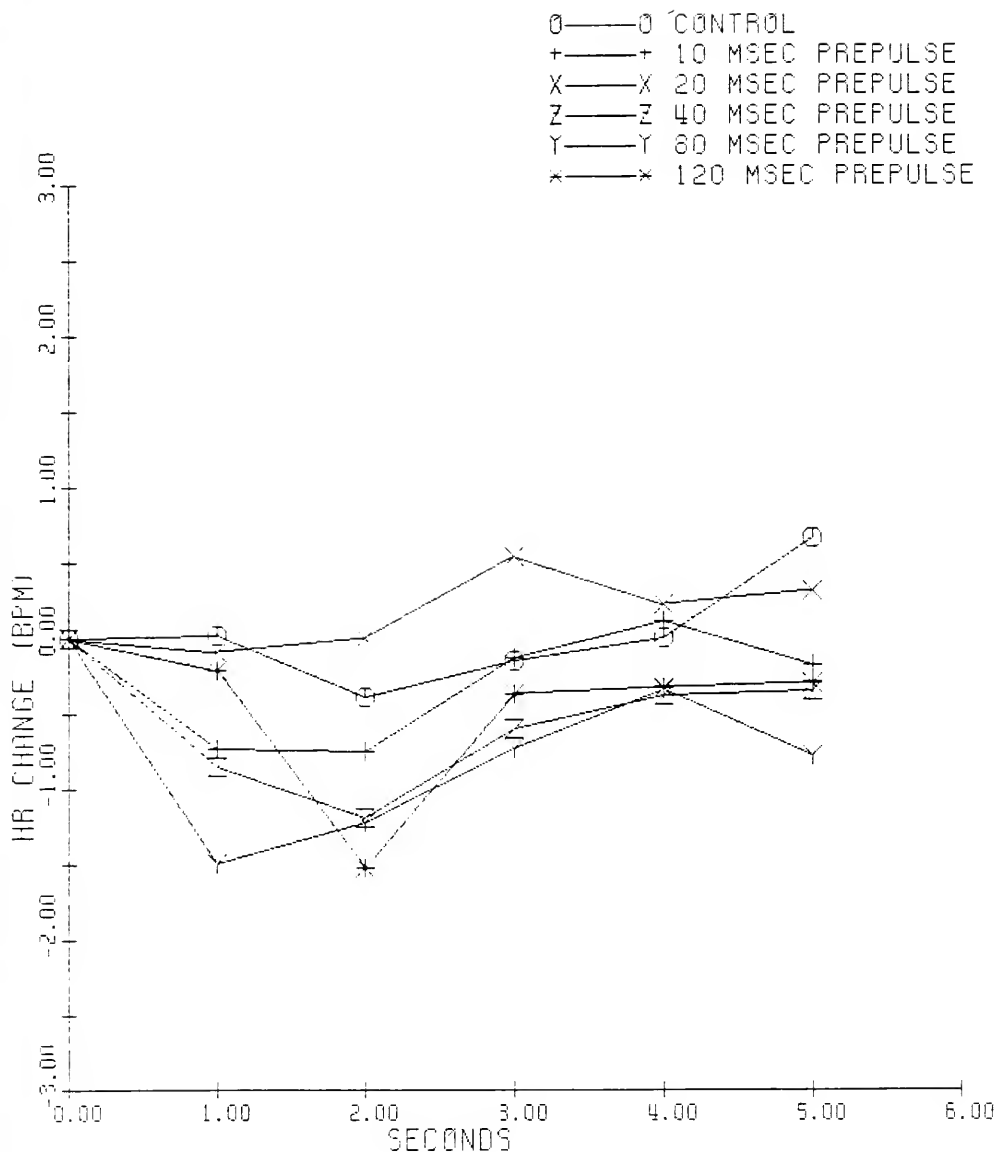


Figure 10. Experiment 4: Mean heart rate responses from old subjects.

APPENDIX  
EXPERIMENT 1: HEART RATE ANALYSES

As implied by Figure 2, stimulus condition was not an important contributor to the HR response of the elderly. While the significant SEC effect ( $F(5,115)=7.71$ ,  $p<.0001$ ) demonstrated that there was a robust response, neither the COND nor the COND X SEC effects reached significance. The young subjects, however, demonstrated not only a large SEC effect ( $F(5,125)=19.49$ ,  $p<.0001$ ), but a robust COND X SEC effect ( $F(40,1000)=3.32$ ,  $p<.0001$ ) as well, implying that the shape of the response was a function of stimulus condition. The significant COND effect ( $F(8,200)=2.05$ ,  $p=.0424$ ) indicated that the stimulus configuration affected overall HR level. The latter contrast was not significant when tested with reduced degrees of freedom.

The results thus far suggested several tentative conclusions: 1) Overall HR level was not a function of age, 2) The elicited response consisted primarily of a large deceleration, 3) The addition of the PS produced a secondary acceleration, 4) The stimulus manipulations had no effect upon the elicited HR response of the elderly, and 5) In the

young group, the HR response was affected by stimulus condition. A tentative appraisal (subject to statistical evaluation) can be proposed. It appears evident in Figure 2 that the decelerative component of the response is increased by the PS, more so for the longer than for the shorter PS. It also appears that the effect of PS interacts with ISI, with the size of the deceleration increasing with increasing ISI.

The next step in the analysis attempted to deal specifically with the effects of PS and ISI. Accordingly, the data for the next analysis were differences between the control response and each of the eight PS responses. For each subject, each second of control response was subtracted from the corresponding second in each PS response. These differences were submitted to a 2 AGE X 2 DUR X 4 ISI X 6 SEC analysis of variance. The most salient feature of this analysis was the interactions involving age. The AGE X DUR X ISI ( $F(3,144)=4.05$ ,  $p=.0085$ ), AGE X SEC ( $F(5,240)=3.51$ ,  $p=.0044$ ), and the AGE X ISI X SEC ( $F(15,720)=2.09$ ,  $p=.0090$ ) effects implied that the analysis should be done separately for young and old subjects. Separate DUR X ISI X SEC analyses were undertaken for the young and old subjects, with orthogonal trends evaluated over the SEC and ISI factors.

The results were quite different for the young and old subjects. The old demonstrated very little effect of the prestimulus. A significant quadratic ISI X cubic SEC effect



( $F(1,23)=4.66$ ,  $p=.0415$ ) as well as a significant quadratic ISI effect ( $F(1,23)=4.69$ ,  $p=.0409$ ) indicated that the response was essentially monophasic with no PS and that the addition of a PS produced small increases in the magnitude of the initial deceleration as well as possibly a later accelerative component. These effects were very weak however, and due to the large number of nonsignificant trends in this analysis, should be interpreted with caution or totally discounted.

The young subjects demonstrated robust effects of stimulus condition. Due to the large number of significant trends, a conservative strategy was adopted for interpretation. Within any effect (e.g. the ISI X SEC interaction) the percentage of the total variance of the model accounted for by each significant trend was calculated and criteria were established for deciding which trends to interpret. The equation for this calculation (adapted from Hays, 1963) is as follows: % total variance = (SS effect + MS error) / (SS total + MS error). The added restriction was imposed upon trends which had already demonstrated statistical reliability at or beyond the  $p=.05$  level. The DUR X ISI X SEC analysis in the young group resulted first in a DUR X cubic ISI X quartic SEC effect ( $F(1,25)=6.63$ ,  $p=.0163$ ). However, since neither the overall DUR X ISI X SEC effect nor any of the other component trends were significant, and since this contrast accounted for only .04%

of the variance, it was not interpreted. The next trends to be considered were those comprising the significant ISI X SEC effect ( $F(15,375)=2.61, p=.0009$ ). Arranged in order of variance accounted for, these were the cubic ISI X quintic SEC ( $F(1,25)=4.42, p=.0458, .01\%$ ), linear ISI X quartic SEC ( $F(1,25)=7.64, p=.0106, .05\%$ ), linear ISI X cubic SEC ( $F(1,25)=7.51, p=.0112, .1\%$ ) and quadratic ISI X quadratic SEC ( $F(1,25)=13.35, p=.0012, .23\%$ ). The quadratic ISI X quadratic SEC was the strongest of these and implied that the effect of the PS was largely upon the decelerative component of the response, and that the effect was strongest at the middle ISIs. The next strongest effect, the linear ISI X cubic SEC, was hesitantly interpreted to imply that there was an effect on both the decelerative and accelerative components of the response which increased with ISI. The remainder of these effects were not interpreted.

The next group of effects which were dealt with were those comprising the significant DUR X SEC effect ( $F(5,125)=7.03, p<.0001$ ). These included the DUR X quintic SEC ( $F(1,25)=8.49, p=.0074, .01\%$ ), DUR X linear SEC ( $F(1,25)=9.90, p=.0042, .21\%$ ), and the DUR X cubic SEC ( $F(1,25)=21.53, p=.0001, .41\%$ ). The strongest effect (DUR X cubic SEC) implied that the 200 msec PS accentuated both the decelerative and the accelerative components of the elicited response moreso than the 20 msec PS. The remaining effects were not interpreted. Finally, the significant SEC effect

( $F(5,125)=9.31$ ,  $p<.0001$ ) produced three significant trends, quartic ( $F(1,25)=6.71$ ,  $p=.0157$ , .50%), cubic ( $F(1,25)=11.49$ ,  $p=.0023$ , 2.1%), and linear ( $F(1,25)=21.35$ ,  $p=.0001$ , 6.3%). The latter two effects implied that, in general, the effect of the PS upon the elicited HR response decreases as seconds poststimulus increase but that there are distinct effects upon both the accelerative and decelerative components of the response. The DUR X ISI effect was significant ( $F(3,75)=3.24$ ,  $p=.0266$ ) but is relevant to overall HR level, not to HR response, and was therefore not interpreted.

The analyses completed thus far suggested the following conclusions: 1) The PS effects HR responding in the elderly very little, if at all, 2) In young subjects, the PS serves to accentuate the decelerative component, and possibly to a lesser extent, the accelerative component, 3) The effects of the PS increase with PS duration, and 4) The effects of the PS are greatest at the middle ISIs (120 and 240 msec), smaller at 420 msec, and smallest at 60 msec.

There are at least two arguments which could be directed at these conclusions. The first is that in the latter analysis, I have dealt with difference scores and not with actual measured responses. In order to answer this criticism, I analyzed the data from the young and old subjects using the actual mean HR responses from the eight PS conditions. The results of these 2 DUR X 4 ISI X 6 SEC analyses were virtually identical to those obtained with the

difference scores, although the  $F$  values were slightly different in some cases.

There is a possibility that the pattern of age differences could somehow be explained by differences in the control (ES alone) responses of the two groups. However, an AGE X SEC analysis yielded nonsignificant AGE and AGE X SEC effects, rendering this criticism implausible.

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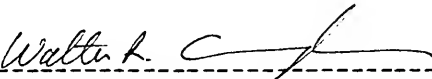
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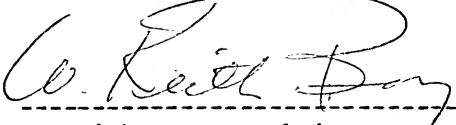
## BIOGRAPHICAL SKETCH

Thomas J. Harbin lives in mirthful camaraderie with his convivant Mimi Saffer, in the former Potano region, now known as Gainesville, Florida. Having it on good authority that a PhD in psychology was the key to security and steady employment, Mr. Harbin has been purposefully pursuing this end at the University of Florida since graduating from Notre Dame in 1976. Tom's people were of good, hearty stock and insisted that he attend L. M. Powers, the catholic high school, in the bustling hamlet of Flint, Michigan, where he lived from his graduation from high school in 1972, until his birth on January 27, 1954.

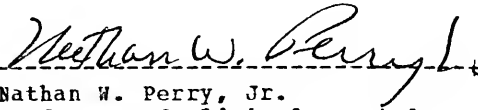
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Walter R. Cunningham, Chairman  
Associate Professor of Psychology

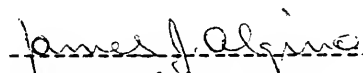
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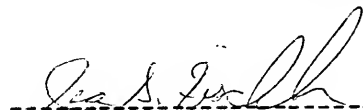
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Nathan W. Perry, Jr.  
Professor of Clinical Psychology

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James J. Algina  
Assistant Professor of  
Foundations of Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

  
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This dissertation was submitted to the Graduate Faculty of the Department of Psychology in the College of Liberal Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June, 1981

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